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SMPTE

801 On the Quality of Color-Television Images and Perception of Color Detail • *Otto H. Schade, Sr.*

819 International Standardization for Motion Pictures and Films for Television • *Deane R. White*

822 International Standardization of Magnetic Sound on Film—A Status Report • *Malcolm G. Townsley*

824 SMPTE Contributions to Standardization in the U. S. • *Frederick J. Kolb, Jr.*

826 Recollections and Predictions • *Barton Kreuzer*

828 Education—A New Era Begins • *Maurice B. Mitchell*

829 The Adventure of Technicolor • *Herbert T. Kalmus*

85th SMPTE Convention • May 4–8 • Fontainebleau, Miami Beach

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On the Quality of Color-Television Images and the Perception of Color Detail

By OTTO H. SCHADE, Sr.

A theoretical and experimental study of the NTSC color system supported by color photographs shows that contrast range and color saturation obtained with commercial tricolor kinescopes provide a larger color space than provided by color motion pictures. In fine detail more than 60% of full color information is transmitted and reproduced by the NTSC system, because the bandwidth restrictions of the electrical color signals (I, Q) do not affect definition in the vertical dimension and have a smaller effect on the reproduction of horizontal color detail than indicated by earlier evaluations which disregarded the two-dimensional nature of the image.

The detail color reproduction appears adequate to the eye, because the color errors remaining are small although perceptible. This fact is significant because the spatial sine-wave response functions of the color discriminators of the visual system are found to be substantially independent of the color of light and similar to the spatial sine-wave luminance response function of the eye.

CONTENTS

A. Electrical and Optical Characteristics of NTSC Color Television System. 801
1. General Characteristics of Color Systems
2. Color Television System for Measurements and Visual Tests
3. Picture-Tube Transfer Characteristics
4. Excitation Purity (Color Saturation)
5. Sine-Wave Spectra and Optical Passbands
6. Effect of Unequal Passbands on Color Detail

B. Some Characteristics of the Visual System and Effect on Overall System Concept. 813
1. Transfer and Wavelength Functions; Incremental Sensitivity for Luminance and Color
2. Sine-Wave Response Functions
3. Equivalent Passbands (N_e) and Number of Receptors in Effective Retinal Sampling Areas
4. System Concepts Unresolved
5. Choice of Color Axes in External Systems Having Unequal Passbands

Conclusions 817
Appendix: Generation of Equiluminous and Constant-Brightness Sine-Waves; Measurement of Sine-Wave Response Functions and Interpretation of Data 817
References 818
Discussion. 818

A. ELECTRICAL AND OPTICAL CHARACTERISTICS OF NTSC COLOR TELEVISION SYSTEM

1. General Characteristics of Color Systems

The reproduction of color in a television or photographic system is based upon the trichromatic theory. The analysis of color in a television or photographic camera requires a discriminator mechanism having three different spectral sensitivities, resulting in three integrals or "primary signals" R, G, B* (or any linear transformation thereof, such as the NTSC values Y, I, Q) which are independent two-dimensional intensity functions of the object point coordinates. In the synthesis of a colored image, luminance and color of all image points are restored by letting the primary signals control three properly chosen "primary lights": the reproducing primaries red, green and blue. The reproduction of color by a linear or a nonlinear system must be independent of illumination intensity to conform with the requirements of vision. A stable color balance necessitates a constant ratio of the three signal functions, which requires:

(a) matched transfer characteristics,
(b) matched spatial frequency spectra of the system, and
(c) matched noise-levels

These specifications express a *registry requirement.* The *registry of three transfer characteristics* is an old problem in photography and a new problem in television, demanding high precision in maintaining relative and absolute gain and black-level stability in linear or nonlinear amplifiers as well as in camera tubes and kinescopes, where sensitivity or response within the image area must be highly uniform. *Registry of the spatial frequency spectra* of three color images requires accurate time-delay and phase equalization in electrical channels and a closely matched image geometry in three scanning rasters. *Matched noise levels* become important when the signal-to-noise ratios are low, because unmatched levels result in a mismatch of transfer characteristics.

For the reason of "compatibility" in television, the color information must be transmitted without increase of video bandwidth together with a luminance signal suitable for monochrome receivers. The two additional color-transmission functions (I, Q) are, therefore, restricted to smaller passbands than the luminance function (Y). (See Sect. 5.)

The present analysis does not concern

Presented on October 22, 1958, at the Society's Convention at Detroit by Otto H. Schade, Sr., Electron Tube Div., Radio Corp. of America, 415 S. Fifth St., Harrison, N.J. This paper is also appearing in the December 1958 issue of *RCA Review*.
(This paper, first received on May 9, 1958; received in final form on November 5, 1958.)

* The spectral sensitivities or wavelength functions $f(\lambda)$ should be such that the primary signals are approximately proportional to the tristimulus values of the object, the tristimulus values being those of the receiver primaries.

Table I. Voltages in NTSC Color System.

	Transmission primaries (Matrix I)				E' Components from Matrix II				Sum E' in freq. range Δf (mc)			Luminance factor for linear system		
Color	E	E_Y	E_I	E_Q	Gun	Y	I	Q	$(Y+I+Q)$ $\Delta f = 0 \rightarrow 0.6$	$(Y+I)$ $0.6 \rightarrow 1.8$	Y $1.8 \rightarrow 4$	$l_{0.6}$	$l_{0.6 \rightarrow 1.8}$	$l_{1.8 \rightarrow 4}$
	1.0				Red	.30	.57	.13	1.00	.87	.3	.30	.26	.09
Red	—	.299	.596	.211	Green	.30	−.16	−.14	0	.14	.3	0	.08	.18
	—				Blue	.30	−.66	.36	0	−.36	.3	0	−.04	.03
												Σ .30	.30	.30
	—				Red	.59	−.26	−.33	0	.33	.59	0	.10	.18
Green	1.0	.587	−.274	−.523	Green	.59	+.07	+.34	1.00	.66	.59	.59	.39	.35
	—				Blue	.59	+.30	−.89	0	.89	.59	.0	.10	.06
												Σ .59	.59	.59
	—				Red	.11	−.31	+.20	0	−.20	.11	0	−.06	.033
Blue	—	.114	−.322	.312	Green	.11	.09	−.20	0	.20	.11	0	.12	.065
	1.0				Blue	.11	.36	.53	1.00	.47	.11	.11	.05	.012
												Σ .11	.11	.11
	1.0				Red	1.	0	0	1.0	1.0	1.0	.30	.30	.30
White	1.0	1.	0	0	Green	1.	0	0	1.0	1.0	1.0	.59	.59	.59
	1.0				Blue	1.	0	0	1.0	1.0	1.0	.11	.11	.11
												Σ1.0	1.0	1.0
	1.0				Red	.89	.31	−.20	1.0	1.20	.89	.30	.36	.67
Yellow	1.0	.886	.322	−.312	Green	.89	−.09	+.20	1.0	.80	.89	.59	.47	.53
	—				Blue	.89	−.36	−.53	0.	.53	.89	0.	.06	.09
												Σ .89	.89	.89
	—				Red	.70	−.57	−.13	0	.13	.70	0	.04	.213
Cyan	1.0	.701	−.596	−.211	Green	.70	.16	.14	1.0	.86	.70	.59	.51	.415
	1.0				Blue	.70	.66	−.36	1.0	1.36	.70	.11	.15	.072
												Σ .70	.70	.70
	1.0				Red	.41	.26	.33	1.0	.67	.41	.30	.20	.123
Magenta	—	.913	.274	.523	Green	.41	−.07	−.34	0.	.34	.41	0.	.20	.245
	1.0				Blue	.41	−.30	.89	1.0	.11	.41	.11	.01	.042
			1				2			3		Σ .41	.41	.41

itself with faults of a temporary nature in the operation of a color system, but with the range and purity of colors obtainable, in particular with the unequal passbands of NTSC television signals and with commercially available color kinescopes. The computed colorimetric performance is checked by measurements, supported by visual observations (color photographs), and interpreted with reference to the performance of color photography and the visual system.

2. Color Television System for Measurements and Visual Tests

The color signals are generated by a light-spot slide scanner (see Fig. 1) followed by three gamma-correction amplifiers and band-limiting filters feeding the cross-mixing network or Matrix I (RCA "colorplexer") for translation of the input signals E_R, E_G and E_B into signals E_Y, E_I and E_Q. The matrix coefficients for the system are given in Table I. After band-limitation by I- and Q-filters in the colorplexer, the signals are translated back to $E_R'E_G'E_B'$ in the inverse Matrix II. The primes indicate that each signal is now a frequency-dependent mixture of components from three unequal passbands as indicated in Table I and discussed later. These signals are then modified by the transfer characteristics and frequency characteristics of the electron guns of the color kinescope and superimposed on the kinescope screen, where they are converted to light energy. Modulation and demodulation circuits (not shown) can be switched in at point M to observe effects introduced by transmission of the multiplexed NTSC signal over a single channel as discussed briefly in Sect. 5.

For measurements of the dynamic transfer characteristic of the system, the light intensity in a fixed small area on the kinescope screen is observed by a multiplier phototube while a calibrated step tablet image is slowly drifting over this area in a vertical direction. The step signal is generated by a color transparency having the characteristics indicated in Fig. 2. The slow vertical drift is generated by synchronizing the vertical oscillator of the light-spot scanner with a stable oscillator differing very slightly in frequency from the field frequency. The screen of the kinescope is thus illuminated continuously in its entire area by the drifting colored test-pattern picture, while the monochrome step intensities are traced on a recorder. The optical step signal is generated in two sections. The main step tablet (a) covers a 70-to-1 range, and a 10-to-1 neutral filter strip (b) extends this range to 700. Measurement of the electrical signal steps at intermediate points of the system furnishes the various transfer characteristics shown in Fig. 3.

3. Picture-Tube Transfer Characteristics

The dynamic transfer characteristic shown in Fig. 3 was measured several years ago on a 21AXP22 metal color kinescope. It follows a power law (close to a square law) with an additive constant B_0, which expresses the black-level illumination or light bias on the screen resulting in a "toe" in the characteristic. The light bias is caused by diffuse electron excitation (secondaries), optical diffusion in the screen and ambient light. It is variable, therefore, and has its lowest value for a dark viewing room and for pictures having a high ratio of peak-to-average luminance. For normal picture material, the range of the transfer characteristic is similar to that measured with the colored test pattern (Fig. 2), i.e., approximately 600 to 1 in a dark room.* This range is much higher than that obtained in motion-picture theaters (60 to 100 to 1) where the light bias B_0 is caused by projection lens flare and ambient light; in fact, it is even higher than the contrast range of the color film positive itself,* which is in the order of 470 to 1.† The large range of the color kinescope cannot be photographed in its entirety on Kodachrome or Ektachrome film, and is further reduced by the color printing process in the various illustrations.

* The reader may compare these values with those given in Ref. 2, showing transfer characteristics of early (1954) color kinescopes covering a range of hardly more than 20 to 1.

† Today's color kinescopes (21CYP22) have an even higher contrast because of reduced electron diffusion by secondary emission.

4. Excitation Purity (Color Saturation)

The degree of color saturation obtainable in a color image is determined by the reproducing primaries and the contrast range of the reproducer. The red, green and blue primaries of the color kinescope are located in the CIE diagram as shown in Fig. 4. A straight line drawn through the white point (illuminant C) intersects the spectrum locus at two points. The *excitation purity* S of a color located on such a line is by definition[1] the ratio of the distance from the color point to the white point, to the distance from the spectrum locus to the white point. The excitation purity is thus specified by a mixture of a spectral light with white light. The fixed light bias (B_0) caused by ambient or scattered light will be assumed to have the neutral color of illuminant C. The addition of this white light moves all color points toward the white point and decreases the excitation purity of the color from the value S_c computed for $B_0 = 0$ (see Table II) to a smaller value S. The purity reduction by a fixed white-light energy is obviously dependent on the excitation level of the color and its relative stimulus energy, defined as follows:

The maximum luminance Y_{max} in a color system is that of the white light ($Y_{max} = Y_{w\,max}$) obtained when the three primary lights (phosphors) are excited to selected maximum luminance values ($Y_{r\,max}$, $Y_{g\,max}$, $Y_{b\,max}$) giving the specified white light (Illuminant C for color television). The maximum luminance of a color (c) is therefore obtained when at least one of the primary lights reaches the excitation limit established for maximum white-light excitation.

The excitation level of a color is hence specified by the excitation factor

$$k_c = Y_c/Y_{c\,max} \leq 1 \qquad (1)$$

The maximum luminance of a color relative to the maximum luminance is expressed by the luminance factor

$$l_c = Y_{c\,max}/Y_{w\,max} \qquad (2)$$

and the relative tristimulus energy of a color is given by the product

$$k_c w_c = k_c(X + Y + Z)_{c\,max}/(X + Y + Z)_{w\,max} \qquad (3)$$

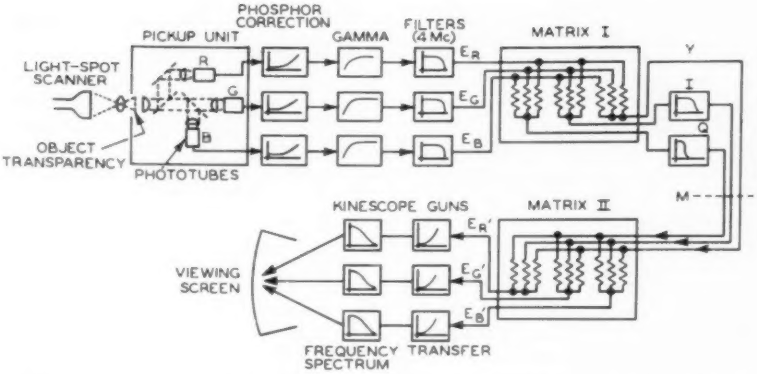


Fig. 1. Block diagram of color system. (**Modulator and demodulator system** (**not shown**) **can be inserted ahead of Matrix II at point** M.)

The tristimulus energy factor w_c can be expressed in terms of trichromatic coefficients (y) and the luminance factor l_c by the simple relation

$$w_c/l_c = y_w/y_c \qquad (4)$$

The tristimulus energy factor w_0 of the light bias is specified by the maximum contrast ratio C,

$$w_0 = w_w/C = 1/C \qquad (5)$$

The mixture ratio $k_c w_c/w_0$ of the relative tristimulus energy of the color to the fixed relative tristimulus energy of the light bias is equal to the distance ratio $S/(S_c - S)$, which gives the desired purity relation

$$S/S_c = k_c w_c/(k_c w_c + w_0) \qquad (6a)$$

and with Eq. (5)

$$S/S_c = k_c w_c/(k_c w_c + 1/C) \qquad (6b)$$

The total relative luminance of the color and light bias energy is the sum

$$Y/Y_{max} = k_c l_c + 1/C \qquad (7)$$

Inspection of Eq. (6a) shows that only an ideal color reproducer having an absolute black level ($w_0 = 0$) provides a constant excitation purity for all colors, independent of excitation (k_c). A plot of excitation purity (S) as a function of relative luminance (Y/Y_{max}) for all possible colors furnishes a *color space* in which arc tan y/x is the vectorial direction of the color from the white point (see Figure 4), excitation purity is the vector length and relative luminance is the elevation.[2] The axis of this space, erected over the white point, represents the gray scale, and vertical sections through this axis furnish *color planes* such as shown in Figs. 5 to 7. The boundaries of these color planes include all possible colors and permit a comparison of different reproducers.

Given the NTSC primaries and constants (Table II) and the contrast range C of the picture tube (see Sect. 3), the

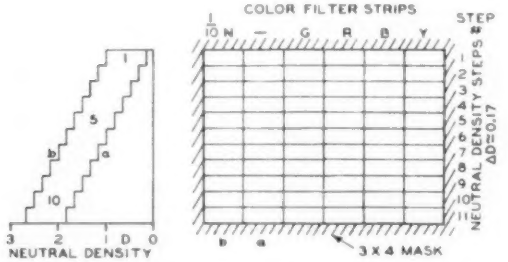


Fig. 2. Test pattern for measuring transfer characteristics.

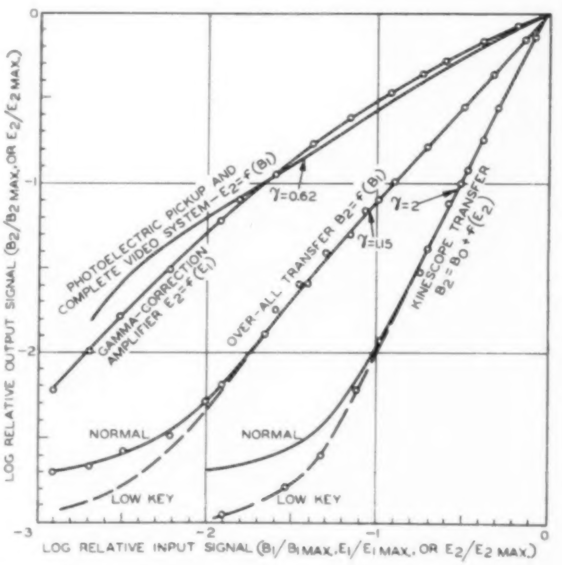


Fig. 3. Transfer characteristics of color system.

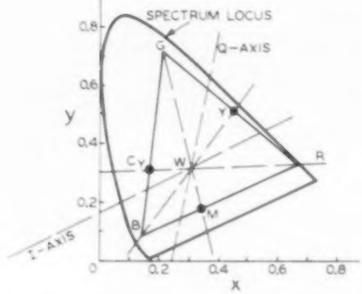


Fig. 4. CIE diagram showing location of television receiver primaries (R, G, B), I- and Q-axes and color planes.

Table II. Tristimulus Energy Factors w_c, Luminance Factors (l_c) and Excitation Purity (S_c), NTSC Standards.

Color	w_c	l_c	Dominant λ (mμ)	S_c	Trichromatic coefficients x	y	z	(See Fig. 4)
White	1.00	1.0	. . .	0	0.31	0.316	0.374	
Red	0.286	0.299	611	1.0	0.67	0.33	0.00	
Green	0.261	0.587	535	0.85	0.21	0.71	0.08	
Blue	0.453	0.114	470	0.88	0.14	0.08	0.78	
Yellow	0.547	0.886	573	0.88	0.45	0.512	0.038	
Magenta	0.739	0.413	535 compl.	0.625	0.345	0.177	0.48	
Cyan	0.714	0.701	490.5	0.52	0.165	0.31	0.525	

Munsell Lightness Value (V) and Luminance (Y)

V	10	9	8	7	6	5	4	3	2	1	0.5	0.2
Y(0/0)	102.56	78.66	59.1	43.06	30.05	19.77	12.	6.56	3.126	1.21	0.581	0.237

lower boundary of television color planes is constructed by selecting a color *on* the color triangle (Fig. 4) and computing the coordinates S, (Y/Y_{max}) of points on the boundary curve with Eqs. (6) and (7) by assigning values between zero and one to the parameter k_c.

The computed boundary extends up to the relative luminance $l_c + 1/C$ at full excitation ($k_c = 1$) of the primary color (or two-component mixture). Higher luminance values in the particular color plane can therefore be obtained only by adding light of complementary color which combines with a certain fraction k' of the color energy to a partial white excitation, having the relative stimulus energy $k'w_w$. The remaining relative stimulus energy of the color is $(1 - k')w_c$. The excitation purity is hence determined by the mixture of the remaining color amount $(1 - k')w_c$ with the amounts of white $k'w_w + w_0 = k' + 1/C$, which leads to the expression for the upper boundary of the color space,

$$S/S_c = (1 - k')w_c/[(1 - k')w_c + k' + 1/C] \quad (8)$$

where $k' \leq 1$ (white excitation factor).

The relative luminance is given by

$$Y/Y_{max} = (1 - k')l_c + k' + 1/C \quad (6)$$

The relative (per cent) luminance scale in Figs. 5 to 7 is distorted, because a better appreciation of the contrast range and color purity of a reproducer is obtained by using the psychophysical *Munsell lightness scale* (V) which divides the dynamic luminance range of the visual system into uniform lightness steps. (The conversion from per cent luminance to lightness (V) is given in Table II.)

A "perfect" color reproduction requires an absolute black level ($C = \infty$) and reproduces all spectrum colors with 100% purity; i.e., the color triangle is replaced by the spectrum locus. The lower boundaries of "perfect" color planes are therefore rectangles, indicated by $C = \infty$ and $S = 1$ up to the relative luminance for the spectral color point as exemplified by the red television primary. The upper boundary of the "perfect" color plane is determined by Eqs. (8) and (9) with $1/C = 0$ and w_c equal to the tristimulus energy factor for the spectral color point. Because their form is not strongly dependent on the contrast C, the upper boundaries of the television color planes R, G, B and Y approach those of the "perfect" color planes for the corresponding spectral color points. It is seen from Fig. 4 that the cyan and magenta regions of the color triangle lie approximately halfway between the spectrum locus and the white point. The corresponding color planes in Figs. 5 and 6 have therefore approximately one-half the width of the corresponding "perfect" color planes. It is further evident that the 600-to-1 contrast range obtained with a color kinescope comes much closer to a "perfect" color reproduction than a motion picture does. The color space boundaries of a color motion picture (broken lines taken from Ref. 2) are by comparison much more restricted and illustrate the basic fact that a subtractive process rapidly loses saturation at higher luminance values, because an increase in film transmission reduces the dye concentration and its color filter action.

To approach the chroma obtainable by the additive color television reproduction, color film could be modified to have a neutral density range of approximately 3.7, to be used with a minimum neutral highlight density near unity to retain a sufficiently high dye concentration. Unfortunately this modification leads to the requirement for ten times more light from the projector coupled with heating and other film problems.

The difference in performance of

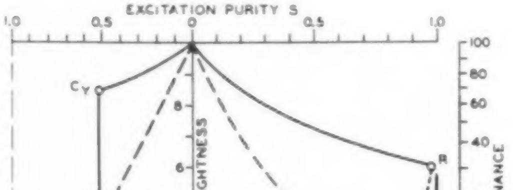


Fig. 5. Red-cyan color plane of additive TV process (Shadow-Mask Kinescope, C = 500), solid lines, and subtractive M.P. process (C = 71), broken lines.[2]

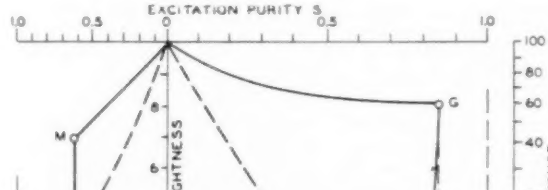


Fig. 6. Green-magenta color plane of additive TV process (Shadow-Mask Kinescope, C = 500), solid lines, and subtractive M.P. process (C = 71), broken lines.[2]

normal color film and color television can be demonstrated strikingly by color photographs of television images having constant luminance (constant Y-signal) and various degrees of color saturation, obtained by a progressive increase of I- and Q-signals (chroma control). Photographs were taken with chroma signals 1, 2 and 3 times normal. The 2 times chroma value produced very high color saturation on the kinescope. The corresponding color photographs, however, taken with *normal exposures*, show only minor increases in chroma, as illustrated by Plates I and II and expected from the color diagrams Figs. 5 to 7, while the denser photographs reproduced in Plates III and IV, taken with one-half normal exposure, give a better reproduction of the kinescope chroma at the expense of a shorter distorted contrast range. Relative chroma values are fairly well reproduced in the prints, although the color purity is lower than in the transparencies and considerably less than in the original kinescope image.

5. Sine-Wave Spectra and Optical Passbands

The transmission of color requires three independent video signals as compared to a single one for a monochrome image. Equal definition in a color image requires thus in theory a transmission system having 3 times the information capacity of a monochrome system. An appraisal of the total information capacity of the NTSC color system can be obtained by comparing its information capacity with that of a color system having three equal independent channels, taking into account a number of nonideal conditions arising in practical systems and deserving particular attention.

The electrical frequency spectrum of a *stationary* monochrome television picture-signal is a line-spectrum of discrete frequency components which are harmonics of the frame frequency (30 cycles). Because of this fact a second line-spectrum, the *color signals* (I, Q), can be added to the monochrome or *luminance signal* (Y) by interleaving its frequency components with those of the Y-spectrum. Interleaving is accomplished by modulation of a color carrier frequency (3.579545 mc) which is made an odd multiple of the half-line and half-frame frequencies. To permit separation of color signals by synchronous demodulators in the receiver, one color signal (Q) is transmitted with double sidebands. It is, therefore, limited to a 600-kc bandwidth, and a 600-kc filter is required after demodulation to eliminate all higher cross-product frequencies. The other signal (I) (also double-sideband up to 600 kc) can have its bandwidth extended by single-sideband transmission. It is restricted to one-half the color carrier frequency, i.e., a bandwidth of 1.8 mc, and a 1.8-mc filter is required after demodulation to eliminate crosstalk.

A perfect separation of the interleaved luminance and chrominance signals can be achieved with interleaved comb-filters when the image is stationary. The inexpensive continuous passband filters used in practical receivers, however, give rise to spurious color signals upon synchronous demodulation in the I- and Q-channels, caused by high-frequency Y-signal components, and the chrominance signal (modulated color carrier) produces periodic errors in the luminance signal. These errors change polarity in successive frames and would cancel out in a linear system when integrated (by the eye) over two frame periods ($\frac{1}{15}$ sec). Practical systems, however, are not linear (all kinescopes are rectifiers), and integration by the eye is incomplete, particularly for bright pictures. The errors, therefore, do not cancel completely even in stationary pictures. They become larger for moving objects and attain full magnitude for random signals such as noise.

The high-frequency crosstalk from the common 2–4-mc region of a "flat" Y-spectrum into the color demodulator band causes orange and blue color tinting of horizontal monochrome detail (coloring of resolution wedges in a monochrome test pattern), and normally fine-grained camera noise in this region of the Y-channel is heterodyned into rather objectionable coarse color-noise ("streaks") by the demodulators, as indicated by the large values of the broken-line cross-product curves in Fig. 8b.

These undesirable effects can be substantially eliminated by introducing a bandwidth limitation of 3.6 mc and a gradual "roll-off" into the Y-channel *before* synthesis of the NTSC signal in the colorplexer of the transmitting station as shown by the solid-line curves in Figs. 8a and 8b. Subsequent re-emphasis (aperture correction) of the Y-channel in the receiver (see Fig. 8c) after removal of the color carrier restores a good Y-signal response. The various degrees of color crosstalk are illustrated in Plates

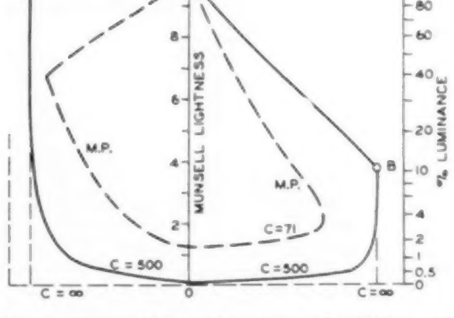


Fig. 7. Yellow-blue color plane of additive TV process (Shadow-Mask Kinescope, C = 500), solid lines, and subtractive M.P. process (C = 71), broken lines.[2]

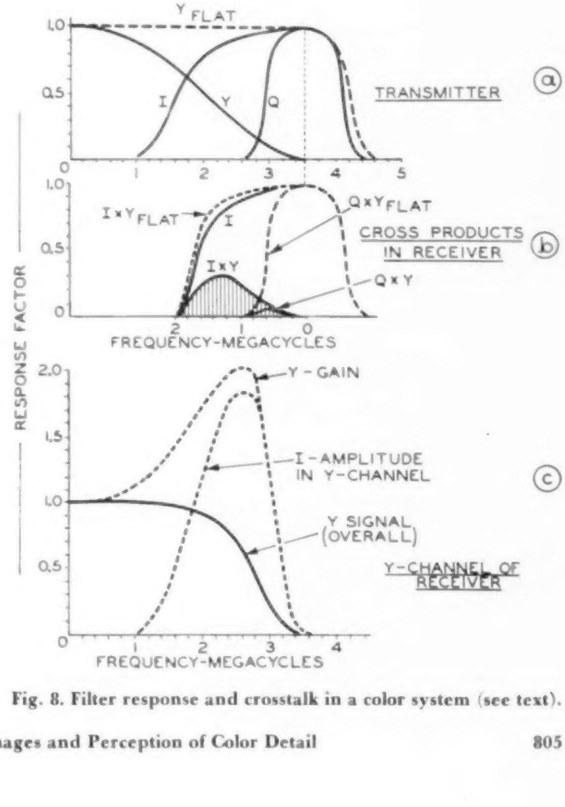


Fig. 8. Filter response and crosstalk in a color system (see text).

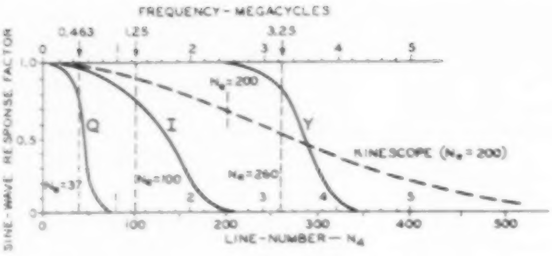


Fig. 9. Sine-wave spectra of horizontal (Y, I and Q) transmission passbands used in the analysis.

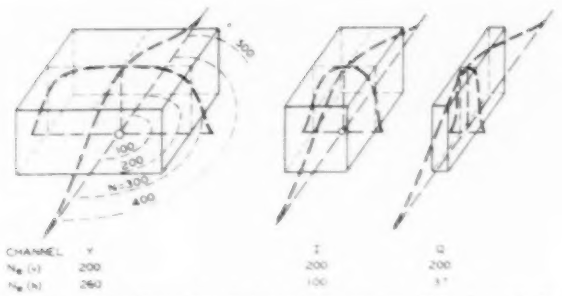


Fig. 10. Two-dimensional sine-wave spectra (Y-, I- and Q-passbands).

V and VI. (The bluish background color of the "white" test pattern photographs resulted from the accidental omission of the ultraviolet filter on the camera lens.) The striking reduction of noise obtained by the bandwidth limitation and roll-off is not reproduced because of integration by the time exposure. Considerable improvement in noise crosstalk is obtained by the bandwidth limitation alone.

The complete elimination of the chrominance signal (modulated color carrier) from the Y-signal (in the receiver) is not possible with continuous filters. It is therefore common practice to suppress the color carrier and its lowest sideband frequencies in the receiver by insertion of a filter (trap) which limits the Y-channel response to 3.6 mc (see Fig. 8c). The carrier interference is thus completely eliminated in large areas, leaving only beat patterns of reduced amplitude (occurring near sharp vertical edges) from the remaining sideband components (I-amplitude in Y-channel, Fig. 8c) which generally contain little energy and permit aperture correction of the remaining Y-channel at the receiver.*

There are thus available three electrical passbands for the transmission of color signals, which correspond to three two-dimensional optical passbands for the color image. Because of the rectilinear scanning process, the three optical passbands in the "vertical" (v) coordinate are alike. They are determined by the raster line number and have the theoretical equivalent passbands:†

$$N_{e(Y)v} = N_{e(I)v} = N_{e(Q)v} = 490 \text{ lines.}$$

The equivalent passbands in the horizontal coordinate (h) are unequal and have the theoretical values

$$N_{e(Y)h} = 320 \text{ lines for } \Delta f = 4 \text{ mc}$$
$$N_{e(I)h} = 144 \text{ lines for } \Delta f = 1.8 \text{ mc}$$
$$N_{e(Q)h} = 48 \text{ lines for } \Delta f = 0.6 \text{ mc}$$

The equivalent symmetrical passbands†

$$\bar{N}_e = [(4/\pi)\, N_{e(v)}\, N_{e(h)}]^{1/2} \qquad (10)$$

are hence

$$\bar{N}_{e(Y)} = 446 \text{ lines}$$
$$\bar{N}_{e(I)} = 300 \text{ lines}$$
$$\bar{N}_{e(Q)} = 173 \text{ lines}$$

Their sum, $\Sigma \bar{N}_e$ = 919 lines, is hence 68% of the sum of three equal passbands of 446 lines each. This simple appraisal of total information capacity in such a color system assumes theoretical rectangular frequency spectra having abrupt cutoff which are neither practical nor desirable for image transmission (monochrome or color) because of strong edge transients and spurious signals generated in the signal-separating process.

The sine-wave response characteristics of practical electrical passbands used in the following analysis are shown in Fig. 9. Their equivalent spatial horizontal passbands are $N_{e(Y)h}$ = 260,‡ $N_{e(I)h}$ = 100 and $N_{e(Q)h}$ = 37. The spatial vertical passband is determined by the cascaded value of the camera and kinescope sine-wave spectra and is in the order of $N_{e(v)} \simeq 200$ for each of the three signals. The equivalent spectrum spaces for the *three practical* channels are the rectangular solids illustrated in Fig. 10. The equivalent symmetrical passbands obtained with Eq. (10) form cylindrical spectrum spaces having the radii:

$$\bar{N}_{e(Y)} \simeq 257 \text{ lines}$$
$$\bar{N}_{e(I)} \simeq 160 \text{ lines}$$
$$\bar{N}_{e(Q)} \simeq 97 \text{ lines}$$

Because of the coordinate transformation or cross-mixing processes and unequal passband limitations, the electrical sine-wave spectra ("frequency responses") for different colors are not equal in this system and can be determined as follows. Referring back to Fig. 1, it is seen that the electrical frequency spectra

* The aperture correction approximately doubles the chrominance signal amplitude in the Y channel.
† See Ref. 3.

‡ This Y channel is somewhat wider than for receiver use (Fig. 8) because it does not contain a trap circuit for the carrier frequency.

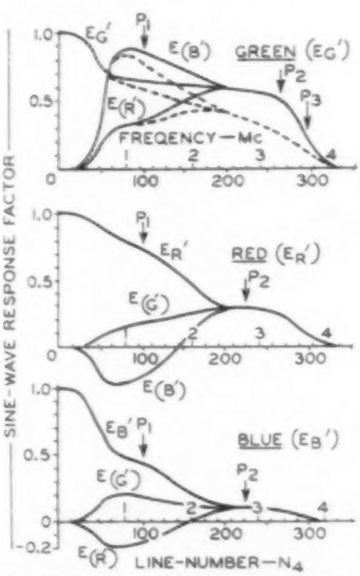


Fig. 11. Horizontal sine-wave-spectrum components at kinescope grid for green, red and blue camera signals.

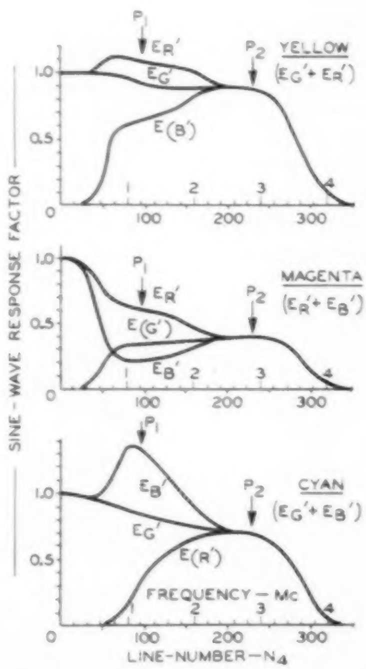


Fig. 12. Horizontal sine-wave spectrum components at kinescope grid for yellow, magenta and cyan camera signals.

of the color signals E_R, E_G, E_B entering Matrix I are alike. The linear cross-mixing process to Y-, I- and Q-signals and back to E_R', E_G', E_B' in the inverse Matrix II does not disturb the signal ratios in the range up to 600 kc where the frequency response in the Y-, I- and Q-channels is alike, i.e., $E_R' = E_R$, $E_G' = E_G$, $E_B' = E_B$. *This range includes the complete electrical frequency spectrum required for transmission of the vertical spatial passbands of the three color functions, which remain therefore unaffected by the cross-mixing processes.* The *horizontal passbands* are normal in the 600-kc range, i.e., a green signal E_G, for example, will result in a green signal E_G' on the "green" kinescope gun and in zero signals on the other two guns as indicated in Table I under the column $\Delta f = 0 \rightarrow 0.6$. In the range from 600 kc to 1.8 mc, however, all Q-coefficients in Matrix II are zero because of the Q-filter cutoff. The matrix is no longer the inverse of Matrix I, and causes signal voltages to appear on all three kinescope grids as shown in Table I. Beyond 1.8 mc, both Q- and I-coefficients are zero, with the result that all three kinescope guns receive equal signals. The last three columns of Table I show that the total luminance would remain constant in all sections of the total passband for a hypothetical *linear* kinescope, although the color or color mixture does not remain constant because of "spurious" signals. The complete video frequency spectra (at the control grids of the kinescope guns) have been plotted in Figs. 11 and 12 for the seven colors listed in Table I. Note that all of them are different, and some of the spurious responses have negative lobes (negative signs of coefficients indicate a phase reversal).

6. Effect of Unequal Passbands on Color Detail

It is a rather widely accepted opinion that the NTSC color transmission provides a three-color presentation for large areas, a two-color presentation for medium-sized areas and a presentation of fine detail without color information. This cannot be true because full color information is transmitted in the *vertical* dimension up to the finest detail (see Section 5 above) which is not affected by the inequality of the electrical passbands. Detail color information is also transmitted in the horizontal dimension, because only the true or "fundamental" color signal components have a normal frequency spectrum including a d-c component, while the frequency spectra of the "spurious" color components contain only horizontal a-c components and represent one-dimensional high-pass filters. It is improper to disregard the difference in d-c components and conclude from Fig. 11, for example, that a vertical line group in a green sine-wave test pattern (for which the blue and red camera signals are zero) would appear in black and white in the fine detail "mixed-high-frequency" region of line numbers $N_3 > 200$.

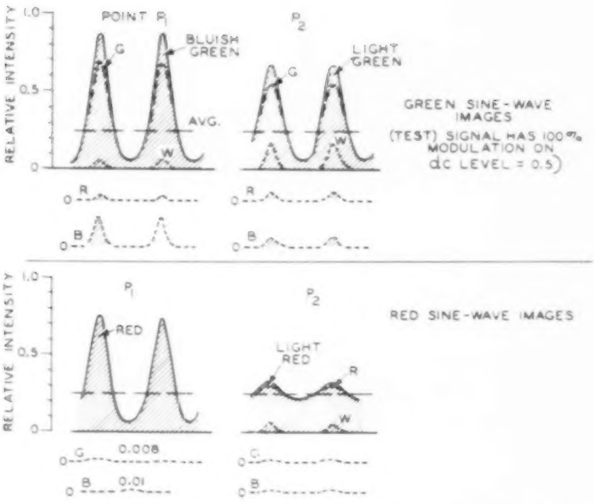


Fig. 13. Intensity function and components (broken lines) of green sine-wave images on the kinescope screen (top), and of red sine-wave images (bottom).

Actually these lines appear green because only the green a-c signal is raised completely above the black level by a d-c component, while the spurious color signals ($E_{(R)}'$ and $E_{(B)}'$) have an electrical zero-level axis, *are rectified by the kinescope*, and can only produce light of much lower intensity during positive half-cycles. In computations of color mixtures for small areas it must be remembered that the normal Fourier relations between impulse forms, unit functions and their spectra do not hold in systems containing nonlinear elements such as a kinescope.

To obtain the correct answer, it is necessary to convert frequencies to intensity functions (waveforms) at the input terminals of nonlinear elements, such as the kinescope guns, project the waveforms over the nonlinear transfer characteristics, pass them through the low-pass filters representing the gun and optical performance, and then combine the light signals to color mixtures as indicated in Fig. 1. The general *effect of the kinescope "spot" size* on fundamental color signals is a reduction of high-frequency components as indicated by broken-line curves in Fig. 11 for small signals. The spurious color signals, however, are rectified by the kinescope, so that each sine-wave frequency is replaced by a series of even-order harmonics which is attenuated more rapidly by the kinescope low-pass spectrum than is indicated by the dotted lines, which lose their meaning as a sine-wave response.

The observed transfer characteristic of the actual kinescope is substantially a square-law characteristic. The intensity function of the fundamental green sine-wave pattern on the kinescope screen (neglecting kinescope spot size) can hence be calculated by squaring the instantaneous sine-wave grid-signal values measured from the current cutoff point, as illustrated in Fig. 13 (top) for two frequencies (points P_1 and P_2 in Fig. 11). Because of the missing d-c component, the squared spurious red and blue a-c signals become very small and only their positive half-waves produce light which adds to the green sine-wave light on the kinescope screen, diluting its chroma as indicated. Similar conditions prevail for test patterns of other saturated colors (see Fig. 13, bottom) as summarized in Table III.

The fine line groups in the "mixed-high-frequency" region retain, therefore, substantially the color of the fundamental signal, although they acquire a spurious tint. Their relative amplitude and luminance are determined largely

Table III. Color of Horizontal Sine-Wave or Periodic Line-Patterns (See Fig. 13)

Object color	P_1	P_2	P_3
Green	Bluish-green (29% blue)	Light green (26% white)	Green
Red	Red (1.5% green)	Light red (17% white)	
Blue	Blue (1.8% green)	Light blue (22% white)	
Yellow	Yellow (5% blue)	Yellow (10% blue)	
Magenta	Magenta (3% green)	Magenta (4% green)	
Cyan	Cyan (2% red)	Cyan (8% red)	

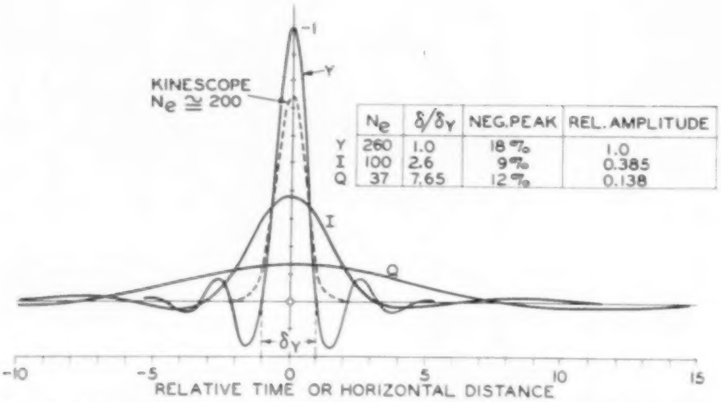


Fig. 14. Unit-pulse forms of *Y*-, *I*- and *Q*-channel from Matrix I and of kinescope.

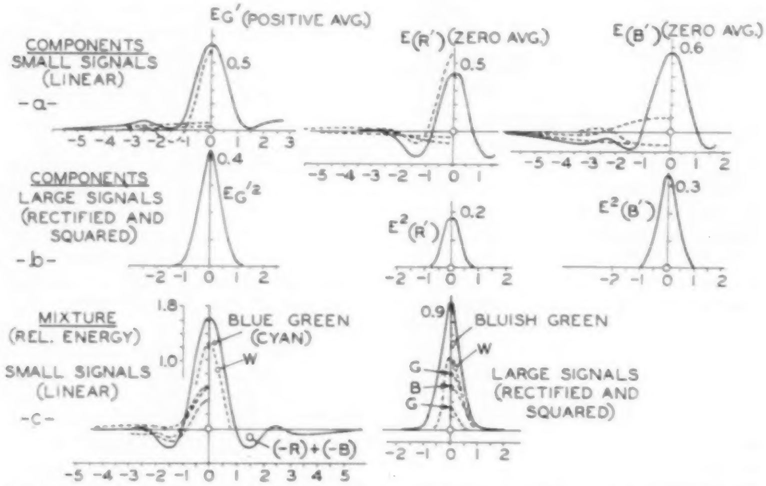


Fig. 15. Relative intensity of impulse components and sums forming the green line-image.

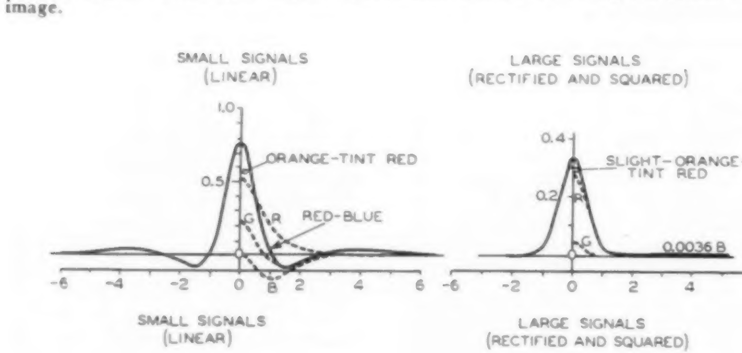


Fig. 16. Relative intensity of red and blue line-images.

by the amplitude of the fundamental color component which is proportional to the *Y*-component of the particular color and therefore lowest for blue (11.4%). These findings are confirmed visually by turning off one or two of the three equal color signals generated by a "white" SMPTE test pattern ahead of Matrix I (see Fig. 1) and comparing the color in the vertical line-wedge reproduction with the pure color reproduction in the horizontal line-wedges of the kinescope image.*

A similar result is obtained by an *analysis of line-images*. The images of fine horizontal lines are transmitted without color change (because of the matched vertical sine-wave response in all channels). The color of fine vertical lines, however, is affected by the unequal horizontal frequency-spectra and is determined by the sum of the three squared impulse components. The impulse-forms computed for unit signals in the *Y*-, *I*- and *Q*-channels are shown in Fig. 14, corresponding to the frequency spectra shown in Fig. 9. For a given color-line signal the impulse-forms at each of the three kinescope control grids are sums of these three impulses modified in amplitude by the amplitude factors for the particular color signal mixture (Table I, column group 2). The squared positive amplitudes of these impulse sums are transduced by the kinescope into light, i.e., into line-images, which are then added and analyzed for color mixture.

The impulse-forms at the control grids of a color kinescope are shown in the top row of Fig. 15a for a green line-object. Note that only the fundamental color (green) has a positive average value (the spurious signal impulses red and blue contain no d-c term). A low-intensity green line-object superimposed on a white background would represent a small signal on a d-c level. In this case the spurious as well as the fundamental signal components are transduced linearly and without rectification by the kinescope, resulting in the impulse sum shown at the left in Fig. 15c. A high-intensity line-object in a black background is a large signal on a zero d-c level, requiring separate squaring of the gun signals to obtain the intensity functions of the three colored line-images on the kinescope screen shown in Fig. 15b, which have no negative amplitudes (clipped by the kinescope). The sum of these optical intensity functions is shown at the right side in Fig. 15c. Since the transfer gain is adjusted so that equal electrical amplitudes result in "white," the amount of white contained in the impulse sum is given by multiplying the smallest one of three common components (*R* in this case) by 3 at any one distance from the line-image center. It is seen that the white dilution is lower in a squared large-signal line-image than in a small signal, which by itself is not a pure color. This condition is also obtained for other colors as shown in Figs. 16 and 17. It follows again that *vertical line-images retain substantially their original hue* somewhat tinted, desaturated or

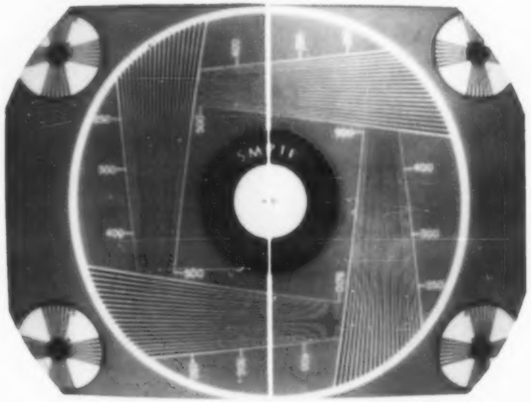
* It is apparent that overemphasis of the electrical high-frequency response by excessive aperture correction increases the spurious color signals and chromatic errors.

I

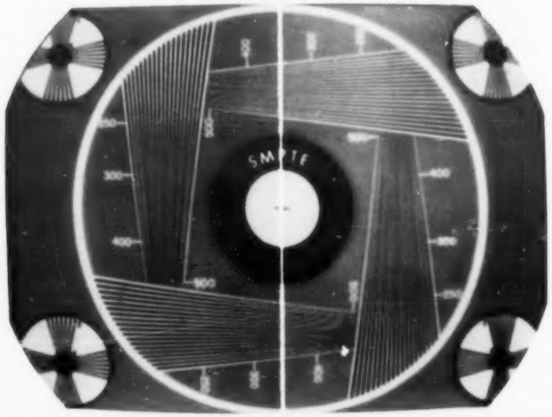
II

III

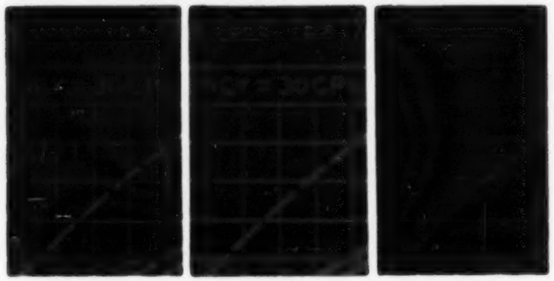
IV



V



VI



VII

VIII

IX

X

XI

XII

XIII

Plates I to IV. Ektachrome performance in recording constant luminance images. Plate I, normal chroma, normal exposure; Plate II, 2X chroma, normal exposure; Plate III, normal chroma at ½ exposure; Plate IV, 2X chroma at ½ exposure.

Plates V and VI. Monochrome test pattern reproductions by NTSC system. Plate V, left, 4-mc flat Y-channel input, demodulators off (no crosstalk); Plate V, right, 4-mc flat Y-channel input, demodulators on; Plate VI, left, 4-mc gradual roll-off Y-channel, demodulators on, subsequent re-emphasis; Plate VI, right, 3-mc flat Y-channel, demodulators on, normal Y-response in receiver.

Plate VII. Samples of three line-object reproductions, 4-mc Y-channel and standard NTSC I- and Q-channels; pure color signals obtained from a white pattern by turning off unwanted color channels in camera.

Plates VIII to XI. Effects of unequal passbands and luminance weighting on kinescope image. Plate VIII, Three independent 4-mc channels (R, G, B); Plate IX, $Y + I + Q$ signals, standard NTSC matrix and filters as in Fig. 1; Plate X, $Y + I + Q$ signals and filters, but G and B reversed to Matrix I and from Matrix II; Plate XI, $Y + I + Q$ signals and filters, but R and G reversed to Matrix I and from Matrix II.

Plate XII. Complete NTSC signal with standard matrix and filters, incuding modulators, multiplexing and demodulator circuits.

Plate XIII. Three independent 4-mc channels (R, G, B).

reduced in amplitude as summarized in Table IV and substantiated visually in the color photographs (Plate VII) by comparison with the normal color reproduction of horizontal line-objects. The illustration shows small sections of $5\frac{1}{4}$-in. by 7-in. picture reproductions. (The faint blue tint in the vertical green lines is barely visible.)

Color transitions at sharp edges can be synthesized in the same manner from the component step-functions shown in Fig. 18. The results are plotted in Figs. 19 to 23. Inspection shows that both color and waveform distortions vary with color and are again relatively smaller in high-contrast transitions than in low-contrast transitions because of the square-law kinescope characteristic.

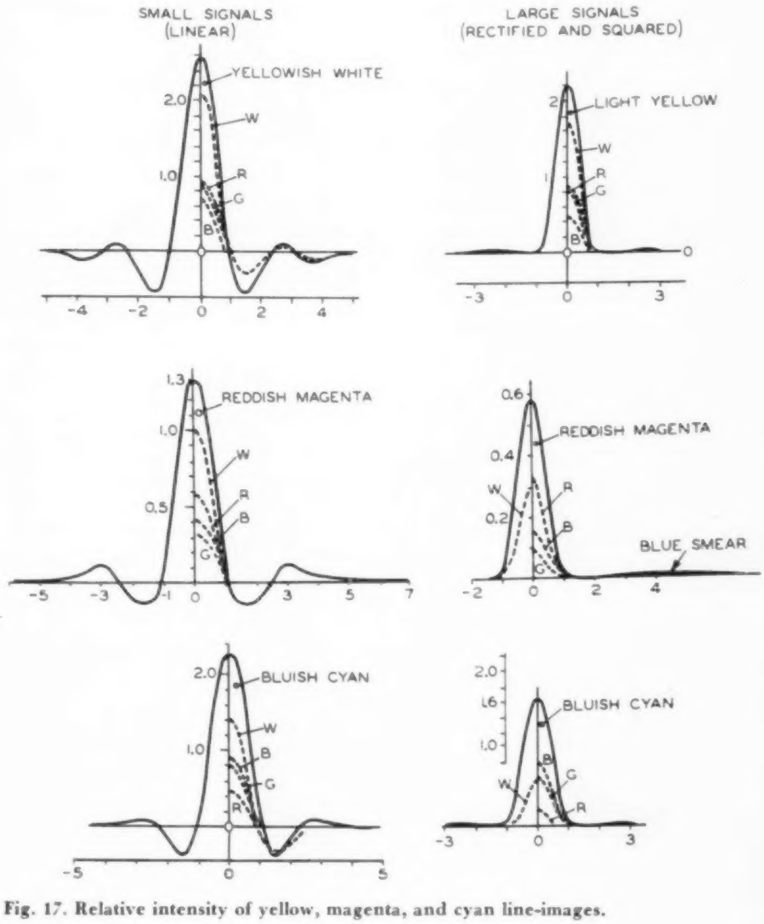


Fig. 17. Relative intensity of yellow, magenta, and cyan line-images.

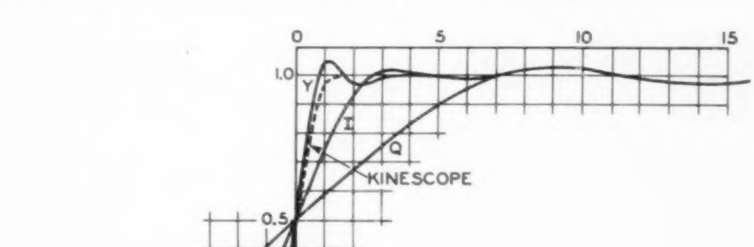


Fig. 18. Unit step-function components from Matrix I and of kinescope.

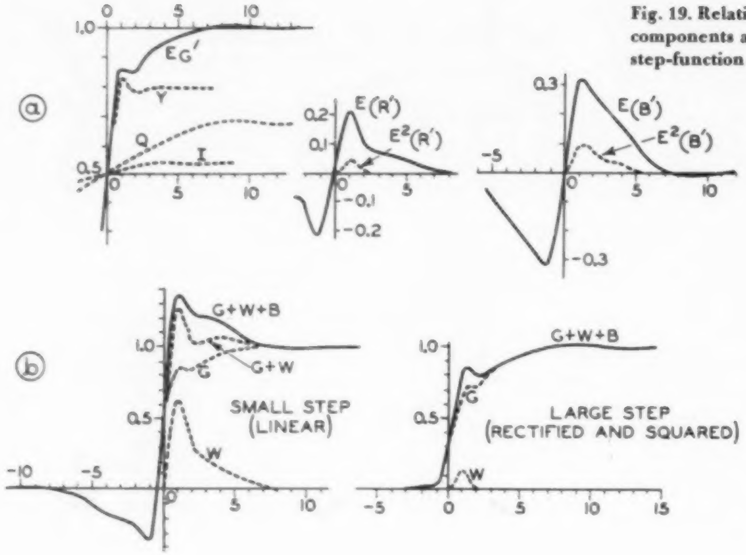


Fig. 19. Relative intensity of step-function components and sums forming the green step-function image.

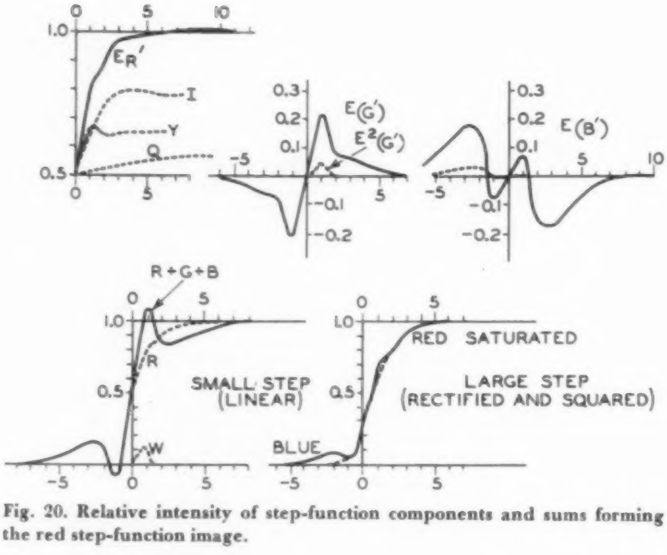


Fig. 20. Relative intensity of step-function components and sums forming the red step-function image.

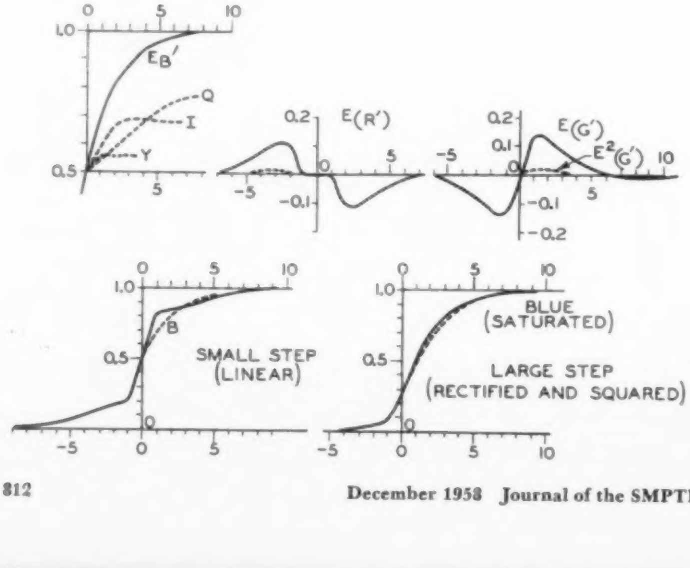


Fig. 21. Relative intensity of step-function components and sums forming the blue step-function image.

It should be pointed out that the effect of camera-tube and kinescope-beam sizes and also the $\frac{1}{2}$-power gamma correction for the kinescope have not been included in the line-image and step-function evaluations. The gamma-correction amplifier itself would not change an ideal unit impulse or a step function, but it does round off the low-level corner of the actual S-shaped step-function from the camera relative to its high-level corner, thus making the large signal step-functions more symmetrical and all step-functions less steep with reduced transient ripples. To include the effect of the kinescope beam size, it is necessary to perform a convolution of its line-image or its step-function response with the computed response forms. The finite kinescope beam size broadens the line-images and transitions somewhat more and further reduces high-frequency transients. The visibility of the luminance errors caused by the unequal passbands of the NTSC system can be assessed by computing the visual lightness of horizontal step-functions and line-images for red, green and blue as shown in Fig. 24. Constant-bandwidth vertical step-functions and line-images are shown for comparison and indicate that the errors in the blue are readily visible as confirmed by observation (compare color plate VII).

It can thus be concluded that *considerable color information is transmitted and reproduced even in fine horizontal detail with NTSC color signals and that a high gamma (square-law) kinescope transfer characteristic is a definite asset because it reduces the color distortion introduced by unequal color-transmission channels.* Furthermore, the fact that relatively small color changes can be seen in the fine detail of color television images raises doubts that the eye's color mechanism does not function when observing fine detail, and suggests a reappraisal of the capabilities of the visual system at normal luminance values.

Table IV. Horizontal Line-Image Characteristics.

Object color	Incremental impulse (linear) color*	Large-signal impulse (rectified, squared) color*	Rel. brightness	Rel. sharpness
Green	Light blue-green (60% white)	Bluish-green (36% white)	Normal†	Normal‡
Red	Red, orange tint (29% green)	Red, slight orange tint (7% green)	Reduced†	Fair‡
Blue	Greenish-blue (17% green)	Blue, green tint (7% green)	Low†	Blurred‡
Yellow	Yellowish-white (27% blue)	Light yellow (21% blue)	Normal	Normal
Magenta	Reddish-magenta (25% green)	Reddish-magenta (17% green)	Reduced	Fair (blue haze)
Cyan	Bluish-cyan (20% red)	Bluish-cyan (12% red)	Good	Normal
White	White	White	Normal	Normal

*The per cent color admixture refers to the area under the main lobe of the impulse or line. Incremental impulse color refers to the increment, not to the total which depends on the color of the setup level.
†See Fig. 24.
‡See Plate VII.

B. SOME CHARACTERISTICS OF THE VISUAL SYSTEM AND EFFECT ON OVERALL SYSTEM CONCEPT

1. Transfer and Wavelength Functions; Incremental Sensitivity for Luminance and Color

The visual system is a very complex system which terminates in a "computer" (the brain) having random connections, and very little is known about its memory and interpreting processes.* There is ample evidence that the system is nonlinear in many of its sections. It is well known that both hue and lightness of colored objects are functions of the surrounding background, although there is no spectral or colorimetric change. It is also known that the apparent "lightness" of a color mixture does not necessarily agree with the luminance value computed as the linear sum of component luminances. (A bluish-white screen, for example, appears brighter than a screen of equal luminance illuminated by a low-color temperature light source.) Observations made by the author on equiluminous sine-wave mixtures (considered later in this paper) indicate likewise that the fixed relation of lightness and luminance given in Table II does not necessarily apply to incremental amounts of the components in a mixture of primary colors, but that it is strongly dependent on the relative total amounts of the primaries.

As to chromatic sensitivity, it is known that the just-perceptible amounts of pure color added to white are about 1% for red and blue and about 2% for yellow and green.[5] The chromatic sensitivity $f/\Delta f$ or $\lambda/\Delta\lambda$ of the eye for spectral colors[6] has two peaks (less than 3 : 1) at yellow and cyan above a substantially uniform level from red (650 mμ) to blue (430 mμ). From the system analysis point of view, it does not appear likely that the wavelength functions of the eye's color discriminating system are as simply related to the wavelength function of its luminance channel as they

* An interesting theory on this subject is discussed in Ref. 4.

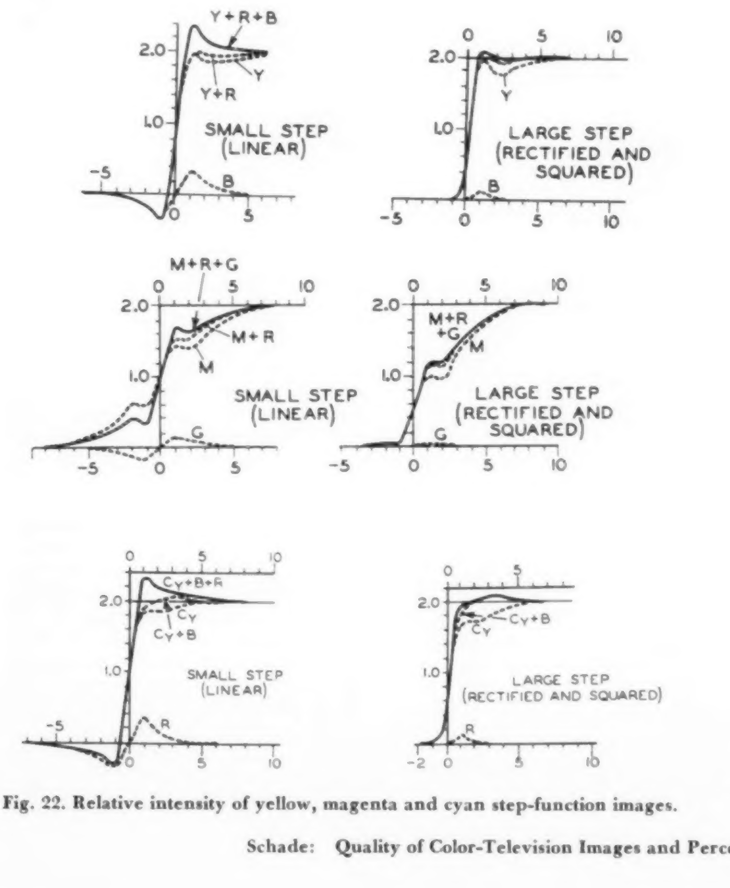


Fig. 22. Relative intensity of yellow, magenta and cyan step-function images.

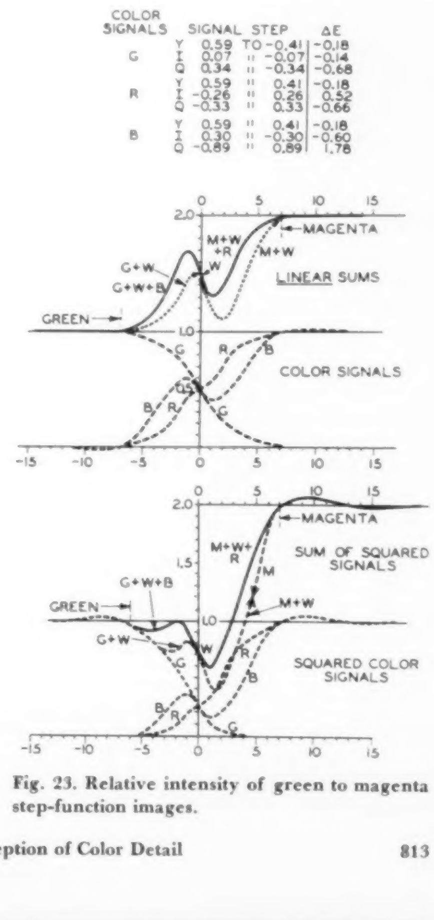


Fig. 23. Relative intensity of green to magenta step-function images.

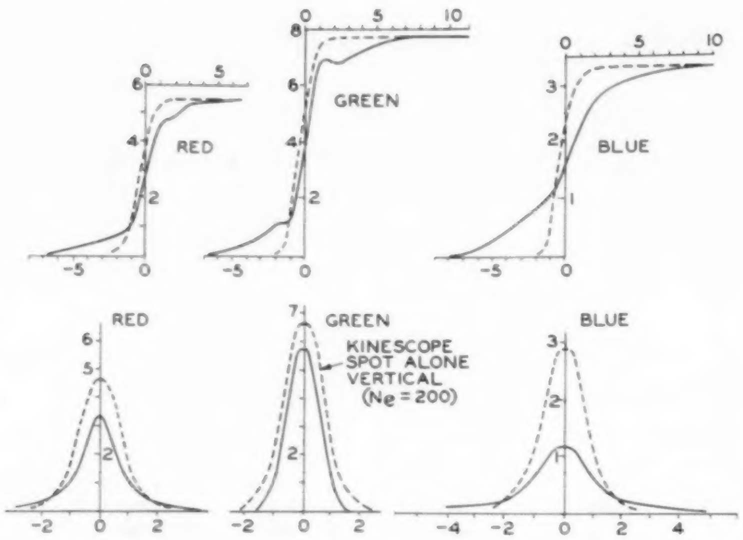


Fig. 24. Step functions and line-images (NTSC) in Munsell lightness values. Solid curves horizontal, broken-line curves vertical coordinate.

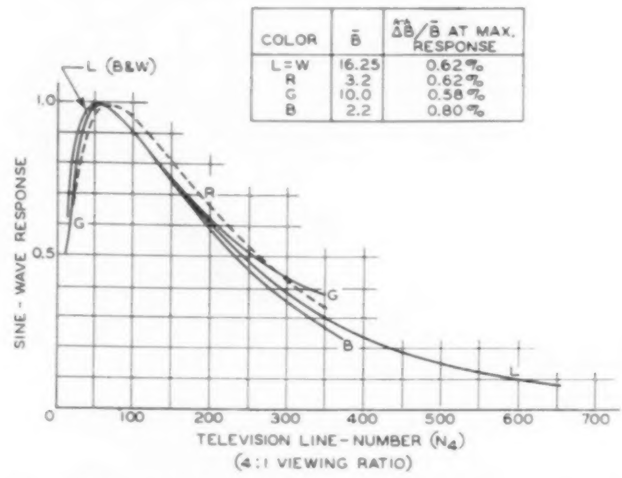


Fig. 25. Response of visual system to single-color sine-wave patterns.

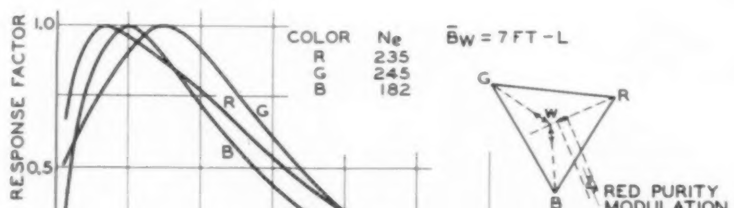


Fig. 26. Response of visual color discriminator system to constant brightness sine-wave patterns (purity modulation).

are in a photographic or color television system, because the eye's luminance system continues to operate at light intensities far below the threshold for color vision.

It has been demonstrated that the eye can see all the calculated defects in the color detail reproduction of the NTSC system, including those in low luminance colors, such as blue, for which the eye's "acuity" is low. It is important to understand clearly that acuity and resolving power are not determined by the spatial sine-wave response alone, because they are strongly dependent on the noise level as well. The remarkable visual constancy of color mixtures over a large part of the photopic range may be taken as an indication that the transfer characteristics, spatial sine-wave response characteristics and noise levels of the eye's color discriminating system are well matched (see Sec. 1 in part A above). Similar noise levels in turn indicate that the "discriminators" receive similar signal levels, or more likely, similar signal differences from the photo receptors in at least three principal regions of the visual spectrum. Their spatial sine-wave response appears to be well matched, because there is no evidence to the contary in their performance (no color fringes, transients or "smears").

It was therefore decided to determine the spatial frequency passbands of the visual color discriminators by sine-wave response measurements, following a procedure previously described for the luminance channel of the eye.[7]

2. Sine-Wave Response Functions

There have been general observations to the effect that resolution and sharpness of images (in microscopy, for example) do not change appreciably with blue, green or red illumination, and that the readability of colored print of equal luminance is fairly independent of color, with red slightly better than green or blue. These observations are not convincing, because they relate to an interpretation of signal combinations (depending on noise level and sine-wave response) from the luminance as well as the color mechanism. The same criticism can be applied in part to the single-color sine-wave response characteristics, Fig. 25, measured by the author on an observer having normal vision. The response of a luminance system can, however, be eliminated by the use of *equiluminous* sine-wave objects, which provide a sinusoidal variation of excitation purity at constant luminance. A red purity change, for example, is represented in the red color plane (Fig. 5) by a sinusoidal modulation of the radius length (horizontal distance), which can be centered near the white axis (near-white background) or may be moved out toward a higher purity point. The generation of such sine-wave patterns on a

color kinescope screen is relatively simple, as discussed in the Appendix.

Sine-wave patterns of constant luminance were set up by measuring the sine-wave luminance distribution with a luminance meter,* and adjusting the component intensity for a constant reading. It was observed immediately that luminance does not have a constant relation to visual brightness. The adjustment for constant luminance (by calculation or meter) differed from the incremental brightness, particularly for equiluminous blue purity sine-waves in a near-white background where the increment-component ratio was in error by several hundred per cent. The flicker test for equal brightness was made by reducing the temporal (electrical) sine-wave modulation frequency to 20 or 25 cycles and adjusting, for example, the blue component (see Appendix) for minimum flicker. Because of the possibility of errors arising from the difference in phosphor decay time for different kinescope primaries, the brightness equality of the positive and negative purity half-waves was judged visually at a higher modulation frequency producing a wavelength of about 2 cm on the kinescope screen. It was found to agree with the flicker test. When such a stationary wave-pattern is observed while one component is varied, a sudden phase shift seems to occur in the sine-wave position when constant brightness is reached.

The constant-brightness condition near the white point requires more nearly† equal stimulus energy than equiluminance of the components, as is most strikingly evident from blue purity modulation tests. It approaches equiluminance when the operating point (background color) is moved toward the spectrum locus, which is to be expected because the luminosity curve is determined from spectrum colors by brightness equality tests. This observation may well explain observed discrepancies in color noise visibility with the NTSC color system, because *equal luminance increments do not guarantee equal increments in visual brightness.*

At the time of this writing only one set of sine-wave response-measurements taken near the white axis ($B_W = 7$ ft-L) is available. The designations red, green and blue in Fig. 26 refer to the color plane in which the purity modulation occurs, although the color in the areas of reduced "negative" purity (negative half-cycles of sine-wave) appears to the eye as a complementary color in comparison with the color of adjacent areas of higher "positive" purity, even at a larger distance from the white point. (The negative blue bar appears yellow, negative green appears magenta, etc.) Lacking a luminance change, the bars appear to have a constant purity as if produced by a square-wave rather than a sine-wave modulation.

The measured sine-wave response-functions of the color discriminator elements in the visual system differ from one another by much smaller factors than the "standard" luminance values. All show a loss of low-frequency and d-c response as in the luminance channel. An analog of the visual system[7] contains therefore a high-pass filter or a negative frequency-limited feedback loop which superimposes a negative image of low definition on the normal image, "inhibiting" the normal low-pass filter response by addition of a negative response as reconstructed in Fig. 27 (see Appendix). The feedback is least for red light and largest for green light, with blue intermediate. More data are required to support a more quantitative analysis of the details of these results.

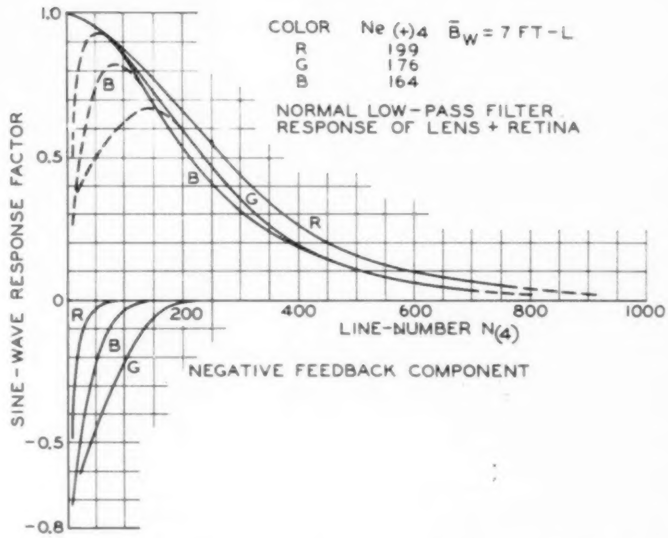


Fig. 27. Positive and negative sine-wave spectrum components of visual color discriminator system.

3. Equivalent Passbands and Number of Receptors in Effective Retinal Sampling Areas

The equivalent passbands (N_{e+}) of the main low-pass characteristics give information on the *effective discriminator areas in the retina* and appear to be in general agreement with Polyak's anatomically well-founded deductions[9] that the red end of the color spectrum is signaled over direct "private line" connections between optic nerve fibers and cones and that it has the best detail response, while green and blue signals involve more diffuse matrix networks in the order stated. The effective sampling area *a* (area of equivalent constant intensity point-image) can be computed from the equivalent passband by $a = 1.16/N_e^2$ (see Ref. 3). It has been shown in Ref. 7 that at a luminance of 7 ft-L the equivalent passband of the eye's lens is $N_{e(L)} = 50$ television lines/mm on the retina. The effective sampling area a_L of the optical point-image produced by the lens of the eye or the retina includes, therefore, 88 2.2-micron cones at this illumination as illustrated in Fig. 28. The normal positive sine-wave response function (Fig. 27) of the visual system is the product of the sine-wave response function of the lens and the sine-wave response function of the color discriminator neuron system. Since the equivalent area of the final point-image in a cascaded system is simply the sum of the equivalent areas of its cascaded components, the equivalent areas a_d of the color discriminator system are obtained as the difference

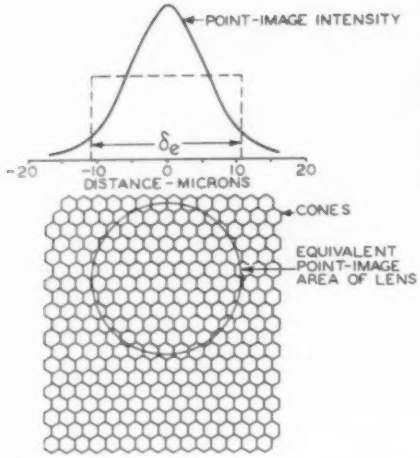
$$a_d = a_m - a_L$$

where a_d = effective area of discriminator neuron system, $a_m = 1.16/(N_{e(+)4}/4.25)^2$ = equivalent area of entire system‡

* Weston Foot-Lambert Meter, New Candle Model 931 with Viscor Filter, corrected for visual response. The meter is designed for kinescope measurements and gave correct luminance readings on the phosphor primaries and their mixtures. The readings agreed with comparative readings taken with a Macbeth Illuminometer.

† This might be expected from a discriminator near its neutral point. A more extended quantitative study of incremental luminance and brightness ratios in sine-wave objects would be of value. The author is aware of many publications (in the *Journal* of the Optical Society of America and elsewhere) discussing discrepancies in the total luminance of a color from standard sums.

‡ The equivalent passband $N_{e(+)4}$ of the overall sine-wave function (Fig. 27) is measured at an object distance equal to four length units (indicated by the index 4); since the effective distance to the retinal image is 17 mm (effective focal length of lens), this length unit corresponds to 17/4 mm = 4.25 mm on the retina, requiring division by 4.25 to obtain lines per millimeter on the retina.



COLOR DISCRIM.	EQUIV. PASSBAND N_e, (L/MM) OF RETINAL AREA	DIA. δ_e OF EQUIV. AREA (μ)	NUMBER OF 2.2μ CONES
R	135	8.0	12
G	75	14.4	39
B	61	17.7	59
POINT-IMAGE OF LENS: AT $\bar{B}$ = 7 FT-L	50	21.6	88

Fig. 28. Diameter δ_e (microns) of equivalent round sampling area of optical point-image and color discriminators of visual system relative to the diameter (2.2 μ) of the photoreceptors (cones).

and $a_L = 1.16/N_{eL}^2 = 1.16/2500 \text{ mm}^2$ = equivalent sampling area of lens.

The diameters obtained for equivalent circular sampling areas a_d of the color discriminator neuron systems are listed in Fig. 28.* The red discriminator receives signal contributions from approximately 12 cones, while the more diffuse green and blue discriminators collect signals from equivalent areas containing about 39 and 59 cones, respectively. The intensity distribution in the actual point-image of the lens and the chromatic sampling areas is approximately gaussian, as illustrated in Fig. 28, and the actual areas include a larger number of cones with partial signal contributions. The relatively large number of cones associated with a single point-image area does give a logical explanation to the known fact that *the retina contains a much smaller number of matrix units (bipolar and ganglion cells) than cones and that this ratio is adequate to derive color signals from the receptors, with only minor effects on the overall passbands.*

4. System Concepts Unresolved

The complexity of the visual system, much of it unexplained, leaves room for much variety with regard to its possible functioning as a color system, and many different theories can be found in the literature.† The number of possible systems, however, is reduced by the high "quantum efficiency" of the eye[7,11] which does not seem to agree with systems of area-sharing receptors, where each covers only a narrow region of the visible spectrum. Given supersensitive receptors, even slight dissimilarities in three spectral response characteristics similar to a luminosity function are quite sufficient to produce excellent color discriminators by signal subtraction and to retain full luminance sensitivity by addition. Like the eye, such a system will continue to "see" images in monochrome when the scene illumination becomes insufficient for operation of its discriminators.‡

The nonlinearity and the matrix system of the retina allow for variation of amplitudes and weighting of respective gains (negative feedback) in combination with the luminance signal, so that the "computer" (the brain) assigns less importance to signals from dark-colored objects in a bright surrounding than it does to small-component signals in a color mixture, or when the general "lightness" of all colors in the viewing field is more balanced. A similar mechanism is effective for pure neutral-luminance signals, where lower-intensity signals are suppressed near strong ones, to enhance contrast by creating a subjective black-level. In such cases one could replace the low-intensity surrounding of an object by a black surrounding without introduction of error, but this obviously does not permit the omission of all low-intensity signals. For the same reason one cannot replace blue or for that matter any dark-appearing color by a dark neutral or black except under specific conditions.

5. Choice of Color Axes in External Systems Having Unequal Passbands

It follows from the discussion of the visual system that, given three unequal passbands for an external color-reproducing system, a preferred assignment to particular colors cannot be made on the basis of the eye's spatial frequency response, since there are apparently no major inequalities between color and luminance passbands in the visual system. One must look toward other characteristics, such as the chromatic aberration§ of its lens, the lightness weighting and the subjective black-level (or feedback) mechanism, which, in a comparison, cause it to attach less importance to "dark" colors, thereby permitting errors in their reproduction to be noticed less frequently.

In the NTSC system the translation of the camera primaries R, G, B into the transmission primaries Y, I, Q containing a luminance channel (Y) was essential to establish compatibility with monochrome receivers. Matrix I also assigns a percentage of the full video passband to each color. In view of the above analysis it appears that a somewhat more panchromatic distribution of these percentages (higher blue content in Y) could be of some advantage.

Having assigned the normal wide passband to the luminance channel of the NTSC color system, there will be no inequality of optical passbands in the reproduction of black-and-white objects. The axes for the remaining two theoretically nonluminous‖ color signals (I, Q) must pass through the white point, and thus affect pairs of complementary colors, such as red and blue-green, orange and cyan, yellow and blue, yellow-green and purple, green and magenta. A balanced psychological weighting condition might be indicated by letting the Q-component be larger for high-luminance colors (which have a large wideband Y-component), but except for the red and blue-green color-pair, all pairs contain one higher and one lower luminance color. The choice of I- and Q-axis directions is thus not very critical. The two color axes should include in general a large angle, and the Q-axis should not come too close to the low-luminance blue primary on one side and should point toward the high-luminance green region on the other side of the white point. These considerations place the I-axis in the orange and cyan region, helping the medium-luminance red. The NTSC system axes have these locations (see Fig. 4).

*The signal integration computed from the measured sine-wave spectra agrees in order of magnitude with the number of synaptic connections from optic nerves over specialized types of ganglion and bipolar cells to the cones in Ref. 9.

†Excellent discussions are given in Refs. 8 and 10.

‡At still lower illumination (scotopic range), cone vision ceases and only the rod system remains in operation.

§The axial chromatic aberration (*J. Op. Soc. Am.*, *47*, No. 6, 1947) of the human eye is approximately 2 diopters from 400 to 550 mμ and less than 1 diopter from 500 to 700 mμ.

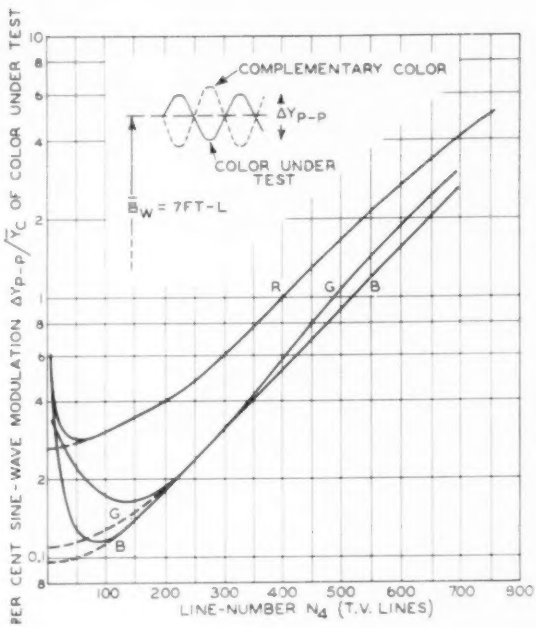
‖Because of the nonlinearity in an actual system, the I- and Q-signals cause small luminance components.

Conclusions

The above analysis as well as visual tests indicate that the bandwidth restriction in the *I*- and *Q*-channels causes small red-colored objects to lose some intensity and blur slightly (relative to white); green- and yellow-colored objects are sharp but lose some saturation, while small blue-colored objects have good saturation but lose intensity and sharpness. Because these effects are smaller in high-luminance colors, disappear toward white, and occur in one (horizontal) direction only, the degradation in a normal two-dimensional color picture transmitted by the NTSC system is relatively small in comparison with a color transmission over three equal independent channels as illustrated by Plates VIII and IX. The relatively uncritical nature of the bandwidth assignments can be appreciated by deliberately disturbing the luminance weighting by an interchange of red, blue or green signal connections at the input to Matrix I, making the corresponding change after Matrix II, and observing the results visually at the kinescope as illustrated by Plates IX to XI. The reversal of luminance weightings for green and blue by interchange of matrix connections (Plate X) can be detected only by the appearance of a transient (following the right-side edge of the hat). The reversal of luminance weightings for red and green by interchange of matrix connections (Plate XI) gives no detectable effect for this subject as compared to the normal reproduction in Plate IX. Critical observation of test-pattern slides reveals that the defects caused by unequal passbands are readily visible and change to different colors when the above interchanges are made, and that there is a preference toward the NTSC choice. In a direct demonstration on a kinescope, most observers (engineers) were unable to recognize the equal bandwidth condition or the interchange of matrix connections when shown a variety of outdoor and indoor color pictures (SMPTE test series and many others).

The analysis has shown that commercial color kinescopes have a color contrast range resulting in a color space which is larger than that of a commercial color motion picture, that color reproduction errors caused by the unequal passbands of the system in fine detail are relatively small, and that they are considerably reduced by rectification in the nonlinear kinescope. It has also been shown that the spurious signals generated in the practical separation of chrominance and luminance signals from the composite (NTSC) signal can be minimized by proper choice of amplitude response in the various band-limiting filters at the transmitter and receiver, and result in a relatively small loss of bandwidth and picture sharpness, as illustrated by Plates XII and XIII. The relative sharpness is well reproduced in the color plates. (Note the slight horizontal edge transients in the NTSC reproduction, Plate XII.) The color saturation, however, is considerably reduced by the printing process.

Fig. 29. Optical modulation intensities required for threshold vision (corrected for kinescope response).



Regarding the performance of commercially available color receivers, it can be stated that the contrast of the color picture tube is as good as that of the tube used in these tests. Pictures received from commercial color broadcasts can be, and on many occasions have been, as good as those observed in these tests. However, with color even more than with black-and-white reception, performance depends on proper adjustments of the receiver controls and, of course, the ambient light level. The fine-detail monochrome performance should be close to the values given (again assuming correct adjustments), but the horizontal color detail is not quite as good, because it is present practice to use a common intermediate bandwidth for both *I*- and *Q*-channels in the receiver.

APPENDIX

Generation of Equiluminous and Constant-Brightness Sine-Waves

A white background is set up first by adjustment of d-c components. The color gun (or guns) producing the desired hue, red for example, is then modulated with a sine-wave signal to generate a vertical sine-wave field, and the guns producing a complementary signal (white minus red equals blue plus green) are simultaneously modulated by negative sine-wave signals (opposite phase) of the same frequency.* To adjust the proper mixture, all guns are first modulated in phase to produce a "white" sine-wave, after which the red gun signal is reversed in phase and adjusted in amplitude for constant luminance or constant visual brightness of the pattern. It is observed that this adjustment varies with the background color (horizontal distance from the white axis) which is, therefore, adjusted first by change of d-c components.

The adjustment for constant brightness (red sine-wave amplitude) must be made for the actual observer to make his luminance mechanism inoperative, because the values (Y) computed from the CIE "standard observer" curve are in error near the white axis as mentioned in Sec. 7. This error is surprisingly large for blue (seven different observers).

Measurement of Sine-Wave Response Functions and Interpretation of Data

The observer views from a fixed distance a uniformly illuminated field on which an extended sine-wave bar pattern is faded in slowly by a master control ahead of the potential dividers for the component ratios. The pattern becomes visible when the brain receives a just-perceptible signal. A plot of the required optical input signal modulation is shown in Fig. 29. The operating point in the color plane was near the white point and had a total luminance indicated in Fig. 29 by $\bar{B}_W$ = 7 ft-L. Since the modulation is given in relative units of the color

*A noninterlaced raster of 500 lines is used to obtain a direct proportionality of optical and electrical frequencies (see Ref. 12).

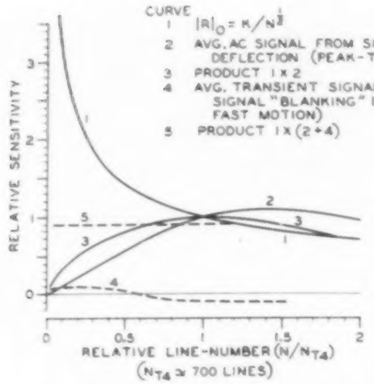


Fig. 30. Effect of signal-to-noise ratio, ocular tremor and transient motion on threshold sensitivity.

under test and relative stimulus values are close to the values, $w_R/w_G/w_B = 1/0.92/1.57$ of the white point, the minimum perceptible stimulus increments of the three colors differ by less than a factor of two from one another at any spatial frequency. The normalized reciprocal values of the sine-wave input signals plotted as a function of spatial frequency f_s or line-number $N = 2f_s$ furnish the sine-wave amplitude response of the visual system (Fig. 26), provided the threshold criterion is independent of frequency. Otherwise a correction is needed. Upon examination, one finds that the visual threshold is noise limited and that detection of any object area requires a certain constant signal-to-noise ratio. Because the area of sine-wave bars of constant length and one-half cycle width decreases in inverse proportion to their line-number, signal-to-noise ratio $(R)_0$ and sensitivity should be proportional to $1/\sqrt{N}$, as illustrated by curve 1 in Fig. 30. It is known, however, that the eye must vibrate (ocular tremor) in order to see detail; i.e., it must generate a-c signals for transmission to the brain (its analog contains a blocking capacitor). The deflection amplitude of the tremor is quite small, 6 μ on the average,[13] which does not degrade the image, but is sufficient to generate strong a-c signals at line numbers where the half-cycle length $1/N$ of the retinal sine-wave image is in the order of the deflection amplitude. The a-c signal, however, decreases toward lower line-numbers and goes to zero at $N = 0$. The average a-c signal developed at different points on the retina due to ocular tremor is therefore a function of line-number, and calculations indicate the function shown by curve 2 in Fig. 30. The deflection amplitude is specified by its reciprocal value, expressed as a television line-number $N_{T(4)}$ for an object distance equal to four length units.*

The action of the tremor counteracts the sensitivity change due to the varying signal-to-noise ratio as shown by the product curve 3, but overcompensates at low frequencies. This deficiency is decreased by a partial d-c response[7] and by the continuous jerky motion of the eyeball when a larger image is observed. One becomes conscious of this motion and its effect in generating a-c signals when a barely visible large object or pattern is viewed, because the pattern fades out when fixed steadily. The signal generation in this case is a series of detached transients (a continuous large deflection would blur the image). A transient image appears after the sudden motion stops, just as in tests where ocular tremor and image motion are prevented artificially and transient vision is obtained after a change of image content. The dashed curves in Fig. 30 show that a constant threshold requires only a relatively small increase in a-c signal at the low-frequency end of the response curve, which is obtainable by intermittent excitation.

In view of these facts, it appears justified to assume a constant threshold criterion in the upper portion of the sine-wave response characteristic of the eye which is thus obtained directly from the measured data. The lower portion is less well defined, but indicates that an analog system contains a high-pass filter in cascade, with the normal low-pass filter representing the optic and retinal structure of the eye. The low-frequency section of the low-pass filter response can be extrapolated by matching the high-frequency section to a possible lens-plus-grain-structure response characteristic (see Fig. 27).

*The reciprocal distance on the retina in television lines per millimeter is given by $N/\text{mm} = N_{(4)}/4.25$.

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Discussion

William L. Hughes (Iowa State College): Would you expand your statement on the interchangeability of blue, green and red?

Dr. Schade: I'll be glad to: I have shown you the circuit diagram, Fig. 1, which shows red, blue, and green signals going into Matrix I for conversion to Y, I and Q signals at its output and then through Matrix II back into red, blue, and green signals. The terminal on the matrix, labeled green, leads to a luminance weighting of 59% — the one labeled blue, to 11.4%. By interchanging the input signals, the blue and green weightings are interchanged. To obtain the correct colors on the kinescope, the output terminals blue and green from Matrix II have to be interchanged also. Because of the matrix connections and filters, the blue is now treated like green in terms of its weighting and the green, like blue. The net overall result comes out the same as far as large area colors are concerned but the frequency weighting is reversed. Reversal of red and green connections at the input of Matrix I and at the output of Matrix II similarly interchanges the weighting of the red and green signals.

Dr. Hughes: Would one conclude from this, then, that for the NTSC system they really had many choices for a narrow band and for wide band, that after you've selected your luminance signal, of course, they are really not too important?

Dr. Schade: Yes: It is not very critical what luminance you assign to the color; but as shown by the analysis, a somewhat higher luminance channel percentage of the blue, say 20% instead of only 11%, might be advantageous. It would give a little more even frequency weighting, so that, for example, a blue-lettered label on a box would be less blurred. But in general this defect

is not very serious and the NTSC choice is in the correct direction as discussed in the paper.

Dr. Hughes: Would you go so far as to say then that in forming the luminance signal one might have taken equal luminance from all three channels and not be very far off?

Dr. Schade: I think the effect would probably hardly be noticed in pictures. There is, however, a compensating effect: the green signal has a high luminance and it is getting a large percentage, 59%, of the 4-mc channel. On the other hand it also gets a high percentage of the narrow-band Q-channel, while the blue signal, which gets a low percentage of the 4-mc channel, gets the highest percentage of the medium channel I-signal. So it is partly compensated by that choice — you can't just make a flat statement.

J. R. Popkin-Clurman (*Telechrome Mfg. Co.*): Would you now advocate that the luminance channel bandwidth be restricted as a great improvement in picture performance?

Dr. Schade: I assume that you mean from the standpoint of crosstalk. In the studio, the cameras all have wide bandwidths, perhaps 6 or 8 mc wide. This wide-channel signal (and noise) is put directly into the colorplexer without band-limiting filters. On a studio monitor, which shows the black-and-white picture, you therefore see a little more definition. In a normal receiver, however, the wide Y-channel causes crosstalk. Now, if you insert a filter into the Y-channel after Matrix I to limit its bandwidth to that of the receiver in the home, you eliminate most of the crosstalk; but in the studio the picture won't look quite as good. I advocate as the simplest change to insert a Bode-type filter having a $3\frac{1}{2}$-mc cutoff into the luminance channel at the transmitter, and most of the color noise will disappear in the receiver without loss of definition, because no commercial receiver exceeds this bandwidth.

Mr. Popkin-Clurman: Your curve showed a considerable cut, starting at around $1\frac{3}{4}$ mc.

Dr. Schade: Yes, one of the curves showed a roll-off requiring aperture correction in the receiver. With that you get very drastic reduction in crosstalk. But the last one of the four color slides I had, illustrated a "flat" channel with a sharp cutoff at 3 mc with no aperture correction in the receiver. No change was made otherwise and you could see that the difference wasn't very large. I have shown many pictures with this arrangement to a number of our engineers and they all liked it because it requires no change in the receiver and no change at the transmitter except for one filter.

Mr. Popkin-Clurman: In respect to the color pictures, in reversing the red for the green, the green for the blue, etc., one of the things, of course, that doesn't show up in these pictures is that the noise gets integrated. Normally we're used to seeing blue noise rather heavily — low-frequency blue noise if you turn up the chroma and you have an excessively noisy system.

Dr. Schade: That is the crosstalk I was talking about.

Mr. Popkin-Clurman: Now what happens when you reverse, say, blue and green? Does the blue noise change to green noise or red noise? Doesn't this become more objectionable from a subjective standpoint than would be apparent from looking at the pictures?

Dr. Schade: The point I'm trying to make here is not that we should reverse the matrix. This is just to show you that the picture in general — forgetting the noise — doesn't change. If you go through forty or fifty different subjects you can divide them into two quality groups and for any condition you get two groups — one judged better, one poorer — which are about equal in size, your choice depending slightly upon the subject. There isn't very much preference. Now with respect to noise, if its visibility was according to luminance, it should not look blue. It does look blue because, particularly near the white point, luminance and apparent brightness increments don't correlate, as discussed in the paper.

Mr. Popkin-Clurman: I believe you stated that in the NTSC system, the color pictures have an added resolution due to resolution in the vertical, even though it may not be present in the horizontal?

Dr. Schade: I'll restate this. In the vertical direction the resolution, or better, the sine-wave response of any television system is determined entirely by the spot size in the camera tube, the number of lines in the raster, and the spot size in the kinescope. In other words, it has nothing to do with the electrical channel, only with the choice of raster line numbers and the size of the spots. Because all the signals in any vertical cross section are transmitted in the lower portion, up to 100 or 200 kc, the video band which is always flat in this range never affects these signals. Since the three color signals, Y, I and Q, are alike up to 600 kc, there is no limitation by the electrical portion of the system at all. We have full vertical definition in all colors. Now, horizontally, you need a wide bandwidth for the higher frequencies to reproduce fine detail and that's where the inequality of the channels comes in.

International Standardization for Motion Pictures and Films for Television

By DEANE R. WHITE

The third meeting of ISO/TC 36, the committee responsible for development of international standards for motion pictures, was held in June 1958. Attention was given to problems arising from both television and theatrical usage. Areas of mutual understanding and agreement were enlarged. Improvement in the ease of international exchange of theater and television program material is the predictable result of this work.

The third meeting of Technical Committee No. 36 of the International Standards Organization was held in Harrogate, England, from June 16 to 20, 1958. Twelve nations were represented by delegations ranging in size from individual representatives to 11 members in the German delegation. The countries included were Belgium, Canada, Czechoslovakia, France, Germany, Japan, Netherlands, Rumania, Sweden, Union of Soviet Socialist Republics, United Kingdom and United States.

The town of Harrogate proved to be a very good location for this meeting. It is a spa or resort town rather than an industrial community, combining adequate hotel facilities with few distractions to interfere with the main work of the committees. The United Kingdom had made good preparation for the meeting, including provision for necessary translation and rapid preparation and publication of documents in the two languages required.

The two previous meetings of ISO/TC 36, the first one held in New York in 1952 and the second in Stockholm, Sweden, in 1955, together with the work done by correspondence in the intervening years, had set the background for this meeting at Harrogate. Seven documents were approved as ISO recommendations in November 1956. These dealt with emulsion and sound record positions in cameras and projectors, two each in the 35mm and 8mm field and three in the 16mm field. Ten were in the form of Draft ISO Recommendations with enough approvals to make their early acceptance as formal ISO recommendations appear assured. Four of these deal with dimensions and locations of sound records, four with camera and projector image areas and two with cutting and perforating dimensions of 16mm film.

Additional background for the Harrogate meeting had been laid by seven interim working groups authorized in 1955 at Stockholm and charged with the solution of specific problems. It had been the hope at the Stockholm meeting that these problems could be resolved by correspondence, but experience again showed that though much progress can be made, final resolution of significant differences of viewpoint and opinion is not readily obtained by correspondence. The ASA, as Secretariat of Technical Committee 36, had requested the interim working groups to prepare and circulate ahead of the meeting summaries showing the status of the work. It was hoped that formal documents would be ready for consideration. This proved to be overly optimistic. Each one of the interim working groups asked for a meeting of the group at Harrogate in the effort to resolve final differences of views before issuing its report. This com-

Presented on October 24, 1958, at the Society's Convention in Detroit by Deane R. White, Leader, U.S. Delegation to the Harrogate Meeting of ISO/TC 36, c/o E. I. du Pont de Nemours & Co., Inc., Photo Products Dept., Parlin, N.J. (This paper was received on September 19, 1958).

bination of interim correspondence with final discussion has proved to be a very effective pattern for work of the Committee and again in this case yielded net total progress.

The first two days of the Harrogate meeting were quite discouraging, and several of us had a very pessimistic view on Wednesday morning of the amount of work which would be done. In retrospect this appears to have been more a period of getting acquainted and settling down to a way of doing business than one of fundamental technical disagreements. It was continually evident that the group as a whole was seeking for the fundamental technical facts which ought to be embodied in these international proposals and was ready and anxious to seek practical solutions to the many little incidental problems that occurred. Such problems arise from a variety of sources but recur rather continuously in the conversion of dimensions from the metric to the English system or vice versa. No general rule could be found by which to make the conversion of dimensions and the expression of tolerances adequate and simple. In many cases the technical significance of the numbers and the tolerances had to be considered as well as formal conversion tables, and methods chosen which would be suitable for the individual case. Progress in the work of TC 36 could have been seriously hindered by unwillingness to meet these points by practical steps designed to recognize the technical facts represented in the dimensions and their tolerances.

The technical results of the Harrogate meeting were summarized in 32 resolutions which were adopted. The actions included:

(1) Revision and release for further processing three Draft ISO Recommendations about which questions had arisen in earlier balloting.

(2) Authorization of preparation and circulation of 13 Draft ISO Proposals.

(3) Organization of 10 interim working groups to continue the technical work of the Committee.

(4) Steps to determine the range of subject matter to be considered by the Committee.

Release of three Draft ISO Recommendations had been delayed by the Secretariat shortly before the meeting pending resolutions of differences of opinions which had developed. Two of these dealt with camera and projector images in the use of 16mm film, and one with the location of recording heads for three magnetic tracks on 35mm film and one track on 17½mm film.

The 13 Draft ISO Proposals authorized affect a number of fields. Two deal with cutting and perforating dimensions of 35mm and 8mm films, respectively. Two deal with wide-screen pictures, their image dimensions or aspect ratios. One deals with the definition and marking of safety film. This incorporates a limitation of the nitrate-nitrogen content of the film base. A later mention will be made of another aspect of this safety-film problem which is still under study. Three involve magnetic soundtracks on film for projection, 35mm and 16mm. One deals with four magnetic tracks on 35mm film. Two deal with recorded characteristics for magnetic sound records on 16mm and 35mm perforated films. One deals with screen luminance for indoor theaters involving either 35mm or 16mm projection. One deals with screen luminance for 35mm review rooms. In each case the Harrogate delegation from the United States considered that the proposals agreed well with U.S. standards and practices and, therefore, it is expected that the U.S. will be in a position to vote affirmatively on these proposals. However, the proposals will be reviewed again as they are circulated in the form authorized at Harrogate, and if further changes need to be suggested, that can be done.

Interim Activities

The ten interim working groups were set up to continue activity in areas considered important but not resolved technically at Harrogate. One of these is continuing the work on cutting and perforating dimensions for 16mm motion-picture film. Draft recommendations exist covering part of the technical material needed in this area, but it is felt that the international standards should encompass more of the material which we have already included in U.S.A. standards dealing, in particular, with the length pitch dimensions shown by experience to be practical. It is also felt that the international work on film dimensions in the 35mm field has piloted, to some extent, a better format of presentation of the data, and it is hoped that this committee can select the correct technical information to include and present it in the best possible format. To this same committee was assigned a second area of international interest, the problem of standardization of 35mm projector sprockets. In the broad sense of the term, this assignment is probably correct since, in general, it is the countries which manufacture film that also manufacture projectors. It is quite possible that, when it comes to handling this particular problem in the U.S.A., the two phases of the subject matter of this one international committee will receive quite different treatment. However, that is a local problem and there was no reason for objecting to the general wishes of the group at Harrogate.

I mentioned earlier the proposed circulation of a draft proposal dealing with the definition and marking of safety film. That proposal limits the nitrate-nitrogen of the base of the film but does not cover a situation which had occurred in the United Kingdom and which led the group at Harrogate to feel that additional coverage was needed. The British delegation reported a film fire of some severity where, according to their diagnosis, a significant contributing factor to the severity of the fire was the use of some kind of protective lacquer over the emulsion which contributed nitrate-nitrogen to the film as a whole. It was, therefore, felt that though the film may originally have been properly classed as safety film, the propriety of that classification had been impaired by the subsequent lacquer treatment. They wish to recognize this hazard by setting an appropriate limitation of the nitrate-nitrogen content for processed films. The group at Harrogate felt that the British experience made such an action appropriate, but they did not have the information upon which to base a proper nitrate-nitrogen limit to meet this specific need. Rather than delay the whole matter of safety-film definition, it was decided to proceed with the document representing the agreement on what would be the nitrate-nitrogen limit for safety film base and assign to an interim working group the new problem of an appropriate limit for processed films.

A desire was expressed on the part of some of the countries represented for a standard in the field of four-track magnetic and optical soundtracks for universal use in the projection of 35mm wide-screen presentations. This subject was assigned to an interim working group.

One of the working groups at Harrogate dealt with sound records recorded on 16mm perforated coated film. They appeared to be close to agreement, though a few points remained unresolved. This matter was left in the hands of an interim working group.

One of the rather difficult problems encountered at Harrogate dealt with recorded frequency characteristics for magnetic tracks. A measure of agreement was reached, but further work was deemed necessary and an interim working group was authorized to deal with this problem as it relates to 35mm and 16mm perforated films. Handling this problem is complicated because it has also been under consideration by a committee working under the authorization of the International Electrotechnical Committee, Technical Committee 29, an agency quite independent of the ISO. An attempt has been made to establish and maintain liaison between TC 36 of ISO and TC 29 of IEC, but that liaison has not prevented jurisdictional questions. This subject matter, the recorded frequency characteristic, is of such importance to ISO/TC 36 that it was not deemed wise to surrender our interest. An attempt was made to improve the liaison with the other group and it is ex-

pected that this interim working group will make progress in its assigned field and maintain adequate liaison with the appropriate subcommittee of IEC/TC 29.

International Exchange of Films

The desirability of standardization of a number of items dealing with international exchange of films was emphasized by the Swedish delegation in the form of a request that study be given to standards for (a) synchronization marks for leaders for studio use, (b) footage numbering of $17\frac{1}{2}$mm and 35mm magnetic sound prints and (c) leaders and trailers for release prints. The duration of the Harrogate meeting did not allow significant attack upon this problem, but membership in the working group will give us the contacts needed to express our views.

It was decided that the work on screen luminance should be continued, extending it in the areas of specifications for directional screens and 16mm review rooms and measurement of stray light and other incidental factors affecting the attractiveness of the motion-picture presentation. The existing committees within the United States can well handle our part of this.

A working group was set up to deal with standards for projection reels for all sizes of motion-picture film, for film cores for all sizes, for cameras pools in the 8mm and 16mm film field and for the designation of winding of films perforated along one edge. These subjects have been of importance here and we will continue to have an interest in them.

One delegation felt strongly the need for the definition of the terms "film meter" and "film foot." This need arises primarily because, for normal purposes, film lengths are determined by the number of perforations or, more accurately, the number of frames, which have gone by a given point and not by an actual linear measurement of the film base itself. Many of us are so accustomed to this measurement that we hardly see the problem involved, but it was pointed out that a misunderstanding on this point could lead to difficulties if, for example, a customer in one country chose to measure the physical linear length of a piece of film which had been prepared and labeled in another country on the basis of the normal perforation count. It is not expected that the technical content of such a proposal will require much work, but there may be a problem of semantics to make sure that the right thing is said.

Another subject assigned to an interim working group is that of picture areas of motion-picture films and slides for transmission by television. Again, this represents an area where we have had important experience and where international agreement will be of value.

During the meeting some question arose concerning the full area of interest of Committee TC 36. The Russian delegation suggested standardization affecting big screen systems, referring particularly to their version of Cinerama, and also emphasized some of the problems encountered in the international exchange of films. They described the latter as a wish to standardize on "a set of materials for international exchange of films," pointing out that in international film exchange some of the factors already experienced in the United States in the use of films for television might be present. Television programing has been a severe taskmaster in requiring that film breaks and total lengths of film be arbitrarily tailored to very fixed time standards. The Russian delegation feels that this problem of time limitation in films may well be expected in international exchange of films and proposes to meet the problem by agreement ahead of time as to normal production length, in addition to the many other factors which affect such international exchange. The representatives at Harrogate did not feel that they were in a position to decide at once on the significance of the points raised, and accordingly the Secretariat was authorized to determine the interest of TC 36 in standardization in this area and to organize a working group if a sufficient number of nations wishes to participate. Another point which came up for discussion in the consideration of the areas of interest of TC 36 was that of inclusion or exclusion of video tape as a recording medium for motion pictures and television. Again resort was had to the appointment of a working group to study the matter and make appropriate recommendations.

I have presented the subject matter of the working groups in more detail than was given to the items which are in the more advanced stages of standardization. The history of the progress of this committee shows that it had to tackle the easy problems first and establish as its first standards some of the practices concerning which there was little question. As it has gained experience it has worked more and more with current problems and has sought to secure appropriate agreement in time for it to be of the most possible value to international business. The subject matter of the working groups now authorized shows that this trend is continuing. It is an attempt to do the work of standardization at the time which will give it the greatest value to the business world.

It is an open secret that the American Standards Association faces a problem in connection with securing the financial support for its entire standardizing activities in the motion-picture field, and this international work represents only one phase of these total activities. It is particularly appropriate that the SMPTE membership know of the technical status of this work and recognize both its technical and business importance so that, as opportunity offers, they can aid in securing the necessary backing to continue this activity on a scale commensurate with the opportunities before us.

International Standardization of Magnetic Sound on Film — A Status Report

By MALCOLM G. TOWNSLEY

The history of international standardization of magnetic sound on film is traced as a typical ISO proceeding and to provide basic information for those who may be able to assist in this standard's further refinement.

STANDARDIZATION WORK in the field of magnetic sound on film has been proceeding at the national level since 1950 and at the international level, through the International Standards Organization, since the Stockholm meeting in 1955. The progress toward agreed standards has not always seemed smooth, and the standards now in circulation for ISO ballot are quite different in form from those under original discussion, but they are in what seems to be far more workable form and represent substantial agreement.

This paper will attempt to trace some of the history of this project as a case history of a typical ISO proceeding, and to identify the present position for the widespread information of those who can contribute to the further refinement of the standard.

The work breaks naturally into two areas: dimensional standards and frequency-response standards. E. W. D'Arcy has represented the United States on the Working Group dealing with dimensional standards, of which Germany has held the Chair. The present author has had the privilege to hold for the United States the chairmanship of Working Group C, which has dealt with the frequency standards, and wishes to extend his thanks to the Sound Committee of SMPTE and to many others in the Society who have guided him in the development of the standards and in reviewing the proposals from the other member countries.

Dimensional standards were arrived at with comparative ease. In 35mm, a few equipment makers came to early agreement on location of sound records for multitrack recordings and there was no great controversy as to standards. It is worth recording that the inch dimensions were rounded in the English-speaking countries and the metric dimensions were rounded in the European countries. This results in sets of dimensions which are not directly convertible, one into the other, but actually in two separate, but compatible, systems. After some discussion, the German system of dimensioning in terms of the head locations was adopted.

In 16mm, the dimensional standards are almost self-legislating. The 100-mil stripe in a position corresponding to the photographic soundtrack and on the face of the film away from the projection lens can hardly be argued with, and agreement was easily reached on the tolerances. One must use as wide a stripe as possible; one must stay out of the picture area; and, depending on the process by which the stripe is applied, the stripe can either extend all the way to the edge of the film or stop just short of the edge. In the discussions at Stockholm, the German delegation voiced a reservation, later withdrawn, on the dimension from the film edge to the inner edge of the stripe. Several countries had National Standards that were in close agreement, and it was possible, with very little trouble, to draft an ISO document, which, after the Harrogate meeting, was sent to ballot as an ISO Draft Proposal.

The synchronization distance on 16mm film became a very interesting problem. There was a U.S. Standard at 26 frames, which was in the process of revision. A Swedish Standard called for a distance of 28 frames. There were no other national standards. At a meeting of a subcommittee of the magnetic subcommittee of the SMPTE Sound Committee in April 1955, tentative agreement was reached to change the U.S. standard synchronization distance to 28 frames.

At Stockholm, it was found that the European countries had reluctantly agreed to follow the U.S. Standard at 26 frames. When it was reported that the U.S. was trending toward 28 frames, there was instant agreement on this distance, and a draft ISO proposal was written accordingly. Later events made this action seem hasty, as we shall see, but here is an example of international agreement before most countries had any national standard in force.

After returning from Stockholm, it was found that one of the major manufacturers in the United States had found it commercially impossible to adopt the 28-frame synchronization distance, and it required some time before this problem was finally resolved in April 1957. Dr. Hans Wohlrab, of the German delegation, pointed out at one meeting of the U.S. committee the crucial importance of having the magnetic sync distance on 16mm different from the photographic track sync distance because of the necessity for having the two types of track inter-cut in television programming, with both in synchronization without re-threading.

The draft proposal for dimensions and synchronization distance was finalized at Harrogate and is now ready for ballot of the member bodies.[11]

The work on frequency-response characteristic was based on the CCIR (International Radio Consultative Committee) characteristic for magnetic tape, which had been published in 1953. This proposal sets forth the frequency-response curve of an amplifier, used with an ideal head, for playback. The frequency characteristic may be specified at the record amplifier, on the film, or in the playback amplifier. The three are interrelated so that if any one is specified, all three are frozen. There was good agreement on the fundamental shape of the curve, but there was a strong American wish for de-emphasis from the CCIR curve in both low- and high-frequency ranges. All European countries wished to follow the CCIR practice of specifying the curve in terms of a time-constant network.

A draft proposal was circulated to the working group, and there began three years of discussion by correspondence. Quite early, Germany and Russia proposed the deletion of the de-emphasis curves, and later Sweden and England joined in this position. By this time, the SMPTE curves had been agreed to in the United States, and the position became a little difficult. Russia, at Harrogate, supported the de-emphasis curves.

During this time, much work was going on to measure the surface-induction levels recorded on the magnetic stripe. Schwartz, Wilpon and Comerci[3] followed up the work of Daniel and Axon[2] and others, and made direct application to measurements of the relative levels on film. German Standards DIN 15538 and 15638[5,6] specified the relative surface-induction levels when they were published for comment in November 1957.

Finally, British Standards Institution CY(ACM) 3114 was issued as a draft for comment in February 1958, with an admirable statement of the problem, and an extremely well-written description of the recording and playback characteristic desired. A revision of this document was used at Harrogate as a model for the draft proposal finally issued.[7]

The British proposal was reviewed with the Sound Committee of the SMPTE, and the American delegation went to Harrogate in June 1958, instructed to agree to the specification being written in terms of the relative surface-induction levels vs. frequency, and to endeavor to secure agreement to the response proposed in the British paper, which is equivalent to the original CCIR curves as

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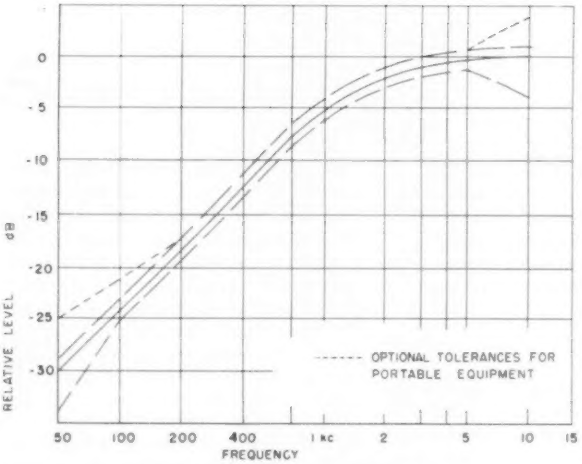

Fig. 1. Recorded frequency characteristic curve for 16mm film — time constant, 100 μsec.

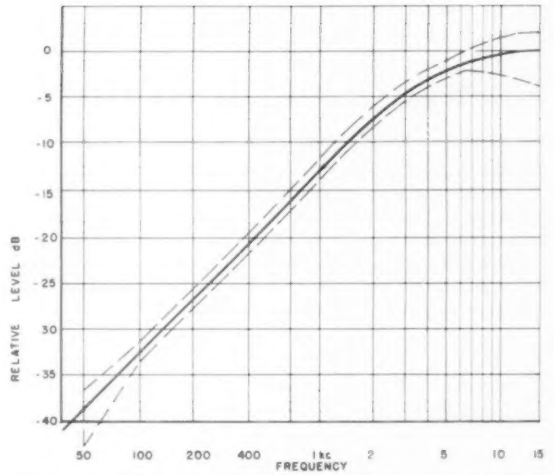

Fig. 2. Recorded frequency characteristic curve for 35mm film — time constant, 35 μsec.

agreed to at Stockholm, but to press for inclusion of the de-emphasis curves of the Stockholm agreement at least as tolerance limits.

At Harrogate, two hours of very cooperative discussion resulted in framing two new documents giving the frequency characteristic in terms of the relative normal surface induction to be recorded on a film from a constant voltage input to the recorder. The shape of the curve of surface induction vs. frequency is defined in terms of the admittance of a series combination of a resistor and a capacitor having a time constant which differs for 35mm and 16mm. A film recorded in this manner is specified to play back flat in a reproducer in proper adjustment.[12,13]

For 16mm, the time constant is 100 μsec, the curve is given in Fig. 1, and the approximate values are given in Table I.

The tolerances shown for portable equipment include the de-emphasis curves desired by American industry. There is some question as to the exact value of the time constant desired. Some German usage is tending to a time constant of 80 to 85 μsec. The SMPTE tentative curve, if it is smoothed a bit, would seem to fit fairly closely to a 70-μsec curve. It would seem appropriate to continue experience with the problem and possibly to reopen the question in time for discussion at the next meeting of ISO/TC 36, which will likely be held in 1961.

For 35mm, the time constant is 35 μsec, corresponding to the CCIR curve; the curve is shown in Fig. 2, and the approximate values are given in Table I. The very large use of 35mm magnetic film in European television has had two consequences: first, it has led to a strong desire to use the same heads and amplifiers for both film and tape and hence to the use of the CCIR curve; and second, to a tendency to carry on standardization through the European Broadcasting Union and the International Electrotechnical Commission. IEC/TC 29 has been active in this field, and there is jurisdictional dispute between that body and ISO/TC 36. A meeting was held at Harrogate between representatives of the two groups, and tentative agreement was reached that ISO would carry on the standardization work where the sound was on perforated film. The IEC group has not completely accepted this view, but the existence of the ISO draft proposals should establish the ISO priority and fairly effectively prevent duplicate work.

The agreement at Harrogate leaves two open problems. First, as has already been said, more experience is needed with the 16mm standard to see whether or not the 100-μsec time constant should be modified in later years. Second, there is still a desire to tie the standards to some absolute reference level of normal surface induction. The work of Schwartz et al. in the United States and the methods published in German Standard DIN 45520[4] have not been correlated, nor has there been sufficient experience in more than one laboratory with either method to be sure that there is sufficient sensitivity and reproducibility for use as a basis for an international standard. It is to be hoped that there will be further work in this direction.

Table I.

Cycles/sec	35 mm, 35 μsec, db	16 mm, 100 μsec, db
40	−40.75	−31.95
50	−38.8	−30.0
60	−37.2	−28.45
100	−32.75	−24.0
200	−26.75	−18.05
300	−23.25	−14.6
400	−20.8	−12.28
500	−18.85	−10.4
700	−15.95	− 7.85
1000	−13.0	− 5.45
1570	—	− 3.0
2000	− 7.5	− 2.1
3000	− 4.8	− 1.0
4000	− 3.2	− 0.6
4550	− 3.0	—
5000	− 2.25	− 0.35
6000	− 1.6	− 0.25
7000	− 1.15	− 0.15
8000	− 0.85	− 0.12
9000	− 0.6	− 0.08
10000	− 0.45	− 0.06
12000	− 0.2	− 0.03
15000	0	0

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SMPTE Contributions to Standardization in the U.S.

By FREDERICK J. KOLB, Jr.

National and international standardization in the fields of interest of the SMPTE are the the Society's responsibility — by agreement with the ASA and other engineering societies. The SMPTE's engineering committees are charged with the technical evaluation and development of such standards; their activities during 1955–58 (the interval between meetings of the ISO) are reviewed in order to present a correlation between American and international standards and to provide a progress report on standardization in the SMPTE.

Since the SMPTE is the sponsor of the American Standards Association Committee on Cinematography and since the ASA has the Secretariat for the International Standards Organization's Technical Committee on Cinematography, our Society is intimately concerned with standardization throughout the breadth of our interest in motion-picture and television engineering.

Moreover, the engineering committees of the SMPTE are the spawning bed for much of this work. The Engineering Committee Manual observes, "Usually a committee's chief function is creation of necessary and acceptable American Standards and/or Society Recommended Practices."

Standardization Progress in the U.S.

At this session, concerned primarily with the progress of international standardization, it seems desirable to review also the recent progress of standardization within the U.S., noting how it has been related to international activity, and also how it has been shaped by technical developments in this country. This summary, a report of the SMPTE Standards Committee, has been prepared with the assistance of all the engineering committees.

We have chosen to describe the accomplishments of the past three years. The period 1955–58 has international significance because it includes the Second ISO Conference on Cinematography at Stockholm, as well as the subsequent interval for consolidation of the Stockholm developments and preparation for the 1958 meeting at Harrogate, which Dr. White has described. Within the U.S. this same period represents an era of rapid development in the television art and of reappraisal and crystallization of new developments in the motion-picture field.

A total of 38 standards and recommended practices were approved by the Society's Engineering and Standards Committees during this period, as shown in Fig. 1. This brought the number of effective and constantly reviewed standards to over 120, including 30 test films, slide sets and other standards references designed for and made available to the industry.

In the U.S. a standard must be nearly unanimously acceptable even though conformance to the standard is voluntary. It is, therefore, difficult to develop standards during the early period of rapid technical progress in a particular field because often the data are not interpreted uniformly by all interested parties. Furthermore, there is a real risk that premature standardization will tend to conceal areas of important technical progress. At the same time, delayed standardization can encourage the choice of incompatible basic premises; incompatibility encourages a long period in which interchangeability is difficult and costs and inconvenience are unnecessarily high. Obviously, the only solution is the continuing great wisdom in each of our Engineering Committees in the choice of the optimum time to initiate standardization.

Figure 1 presents a very preliminary evaluation, however, since the number of processed standards is not a real indication of the work involved or even of its technical importance. Figure 2 describes the 149 standards drafts processed by the SMPTE Engineering and Standards Committees during the same period (1955–58). Even these are not the complete story, but each standards draft does represent a thoughtfully assembled proposal developed from careful preliminary studies and seriously considered for formal adoption.

In these observations we begin to sense the magnitude of the technical tasks and the difficulties of establishing a consensus. It will be noted, for example, that the progress of the Film Dimensions Committee was achieved with less discussion and revision of proposals than the more fermentive progress in the Sound Committee and the 16 and 8mm Committee. Furthermore, here is evidence of current progress toward standardization in a greater number of technical fields.

While it may appear from Fig. 2 that most of the recent work on standardization has been done in well-established fields of engineering, this would be a superficial interpretation. Actually, completely new areas of interest have arisen within established technical fields, such as the commercial emergence of magnetic sound, the mushrooming applications of 16mm motion pictures and the changing pattern of processing laboratory business.

Furthermore, much of our progress in standardization benefits the whole field of motion-picture and television engineering even though primary responsibility has been assigned to one particular engineering committee. For example, the Television Committee requires film dimensional standards in the foundation of its developments; the Color Committee builds upon the preliminary work in laboratory practices; and all the activity keys into a stable pyramid of *industry* progress. Formal expression of this interdependence is given by the Standards Committee organization which brings together the Chairmen of all the Engineering Committees.

International Implications of U.S. Standards

Roughly one-third of our committees' activities were concerned with proposals of international interest defined at the 1955 ISO meeting, as shown in Fig. 3. Classifying the standards drafts considered by our committees, about 7% of the effort was devoted to final work on American Standards which were essentially adopted directly as ISO proposals. About 33% of the effort was spent on internationally significant standards where the ISO proposal differed somewhat from the corresponding American Standard and where further work was needed to determine how each should be drafted. About 60% of the work was in fields not suggested by the 1955 ISO Conference—although as Dr. White has pointed out, a portion of this work was done in anticipation of discussions at the 1958 ISO Conference.

Although we have here indicated that ISO activities did not dominate standardization considerations in the U.S., Fig. 4 indicates that the American Standards have in the past been very important in establishing the final ISO recommendation. At the 1955 meeting a total of 33 proposals were considered or were outlined and requested in resolutions of the meeting. Of these, 33% were essentially equivalent to the adoption of American Standards; an additional 55% were similar to American Standards, usually without serious deviation but

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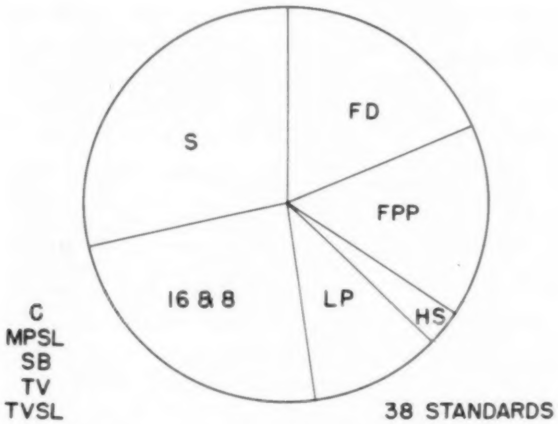

Fig. 1. Standards and Recommended Practices approved 1955–58, showing distribution of 38 Standards and Recommended Practices among the Society's Engineering Committees.

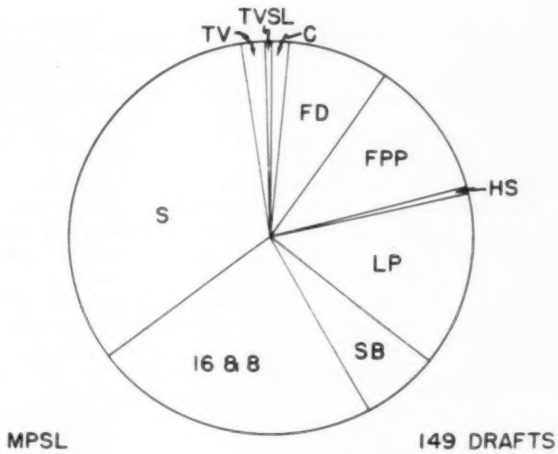

Fig. 2. Standards Drafts balloted 1955–58, showing distribution of 149 drafts among the Society's Engineering Committees.

Engineering Committee names: C, Color; FD, Film Dimensions; FPP, Film-Projection Practice; HS, High-Speed Photography; LP, Laboratory Practice; MPSL, Motion-Picture Studio Lighting; SB, Screen Brightness; 16 and 8, 16mm and 8mm Motion Pictures; S, Sound; TV, Television; TVSL, Television Studio Lighting.

requiring some restudy and revision for complete compatibility. In only 12% of the proposals were there serious differences requiring a basic review, additional data and perhaps a significant future compromise. Of course, this favorable situation resulted partly from the preliminary status of ISO activity and the natural tendency to tackle the easier problems first. As Dr. White pointed out in his report, it is already apparent that the areas of easy agreement are diminishing and there is a corresponding premium on early rigorous technical studies.

The Society's Engineering Committees have this goal firmly in mind, although their agendas will continue to be shaped primarily by the developing needs within the U.S.

SMPTE Engineering Committee Agendas

The situation and *developments in standardization* within each of the fields of our current Engineering Committees can be summarized as follows:

Color Committee. Density measurements on color films, particularly measurements of soundtrack density, are under study. A monumental definitive outline of the principles of color sensitometry and usage has been developed.

Film Dimensions Committee. Recent studies of standardization have been directed by the increasing importance of 16mm film, and also by the industry's concern for optimum steadiness and uniformity which are partially controlled by the dimensional characteristics of the film. There is in addition a program to review all film dimensional standards in order to provide uniformity where desirable and insure a consistent set of specifications and tolerances.

Film-Projection Practice Committee. Changes in the projection mode during the last five years have stabilized to the point that a study of projection apertures, sprockets and other projection standards has been resumed in the light of new developments, information and requirements.

High-Speed Photography Committee. The varied and specialized nature, together

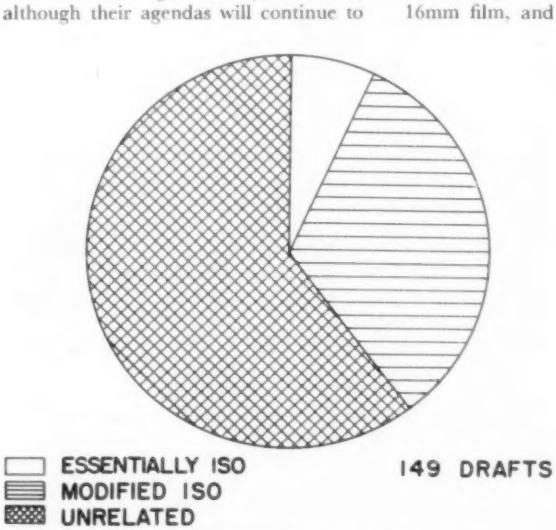

Fig. 3. Relationship of SMPTE Engineering Committee Standards Drafts to ISO Draft Proposals, showing portion of engineering committee work, 1955–58, related to subjects under international consideration.

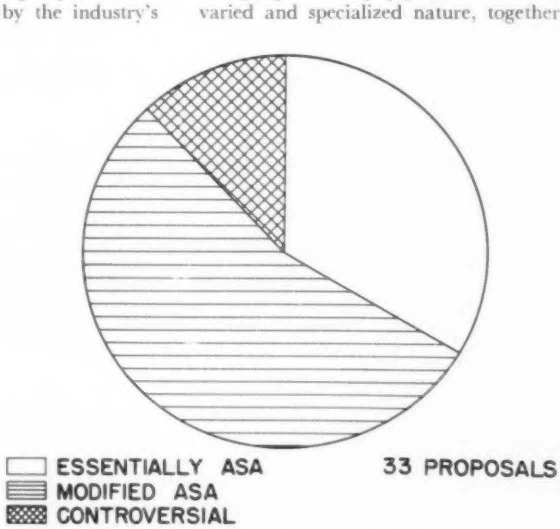

Fig. 4. Relationship of ISO Draft Proposals to American Standards processed by SMPTE Engineering Committees, showing extent of agreement between U.S. practices and international proposals advanced 1955–58.

(This paper was received on November 10, 1958.) greater number of technical fields. usually without serious deviation but

with the rapid growth, of work in this field has encouraged divergent approaches. The Committee is hopeful that the need for standardization has become sufficiently apparent and the pattern of operation sufficiently stabilized to permit progress in standardization.

Laboratory Practice Committee. With the changing pattern of motion-picture laboratory operations, the Committee has proposed some standards and is studying others reflecting the increased importance of 16mm film and the need for agreement in nomenclature of new terms. A Canadian subcommittee is busily engaged on recommendations for standardization of sensitometers and densitometers. Additional studies are directed toward those needs highlighted by the increasing laboratory dependence upon photographic control.

Motion-Picture Studio Lighting Committee. Need for standardization in this field has appeared in spurts, with activity currently in a lull between such efforts. Specification of light flux and its control are under study. International agreement on standard light sources and their characteristics is under study cooperatively with the CIE.

Screen Brightness Committee. Following a period of rapid change in the presentation of motion pictures, the Committee has been studying screen brightness problems in review rooms and in indoor and drive-in theaters. The prevalence of high-brightness indoor presentations, together with the use of directional screens, has so complicated the specification of screen brightness that the whole situation, both specifications and methods of measurement, is under review.

16 and 8mm Committee. An increasing professional importance of 16mm film has led to an extended study of the usage of this film width. A number of basic standards have been processed. Additional standards and test procedures are underway, most of these being drafted in such a way as to indicate the direction of improved quality in the future development of 16 and 8mm film usage. Engineering studies have emphasized the errors in some long-standing assumptions, and the need for standards so written that their interpretation is unequivocal.

Sound Committee. Through a series of ad hoc committees — many cooperating with other engineering committees in the Society — the Sound Committee has prepared a number of standards covering the adaptation of magnetic sound to 35mm, 16mm and 8mm films, together with the procedures for recording and testing. Because of international disagreement on optimum reproduce characteristics, a great deal of experimental work and study has been expended in seeking conclusive data. This very active program and its international implication have been discussed much more fully by Mr. Townsley.

Television Committee. During the period of extremely rapid technological advance, the entire SMPTE offered its experience and judgment and took an active part in the drafting of sound, universally acceptable standards. More recently the Television Committee has found progress considerably slowed. With the growing importance of interchangeability, however, successful advances are again being made and the Committee hopes that the many specific areas where standardization would be helpful can be explored profitably.

TV Studio Lighting Committee. This committee, also caught by the forces of rapid technical change, can now anticipate increased opportunities for constructive standardization. A comprehensive Recommended Practice on the evaluation of lighting units has been developed.

Video-Tape Recording. Newest of the engineering committees, this month-old group was organized because of the pressing need for standardization in this field. They are very hopeful that a comprehensive agenda can be brought to fruition.

Nearly all these committees have, of course, been studying other engineering problems not related to immediate standardization and therefore not herein reviewed.

It is the responsibility of the SMPTE through these Engineering Committees and through others which may be established as the need becomes apparent to continue developing standardization proposals wherever such effort would *expedite technical progress and the utilization of progress.* The pattern of such standardization aptly describes the area of technical improvement which has been consolidated and incorporated into motion-picture and television engineering.

Recollections and Predictions

By BARTON KREUZER
SMPTE President

(In his speech of welcome, President Barton Kreuzer dramatically contrasted the state of the world and of the Society in October 1938, when the Society last convened in Detroit, with the present. He stressed the present importance of educational television and predicted future developments in space photography. He also noted that 20 years ago at the Detroit Convention, Herbert Kalmus, who this year was made an Honorary Member, was awarded the Progress Medal.)

Recollections

In October of the year we last met in Detroit, Hitler's Nazi Storm Troopers were starting their march through Europe. Austria had been seized without a shot having been fired and Czechoslovakia had fallen. Here in the United States, *You Can't Take It With You* was playing in the motion-picture theaters throughout the country and was soon to win the Oscar for the year. Bette Davis was starring in *Jezebel.* "Thanks for the Memory" was number one on the Hit Parade and the group that met in Detroit that year was known as the Society of Motion Picture Engineers.

(In January 1950, the name of the Society was changed from the Society of Motion Picture Engineers to Society of Motion Picture and Television Engineers. Papers presented at the Detroit Convention in 1938 were, even then, indicative of the far-reaching changes gradually taking place through the industry.)

Among papers presented at that Convention were:

"Some of the Problems Ahead in Television" by I. J. Kaar of the General Electric Co.

"Some Production Aspects of Binaural Recording for Sound Motion Pictures" by W. H. Offenhauser, Jr., and J. J. Israel, of New York.

"The Evolution of Arc Broadside Lighting Equipment" by Peter Mole, Mole-Richardson Co.

"Chemical Analysis of an MQ Developer" by R. M. Evans and W. T. Hanson, Jr., Kodak Research Laboratories.

"Some Television Problems From the Motion Picture Standpoint" by G. L. Beers, E. W. Engstrom and I. G. Maloff of RCA.

This was also the year when Dr. Herbert T. Kalmus received our Society's Progress Medal Award. That Convention took place just twenty years ago, in October of 1938.

The Present

Our Society is certainly no stranger to the Detroit area, since a very considerable amount of television, educational and commercial films, and related activities are carried on in the region which is roughly encompassed by the Chicago, Minneapolis, St. Paul, Detroit, Ontario and Cleveland complex. It is estimated that in this area we have upwards of 1200 members, and here, too, there are about 200 television stations many of which have their own film-production departments. In this part of the continent there is, perhaps, the largest concentration of nontheatrical film-production activity in the world. Among the universities which have film departments and are engaged in television production and broadcasting activities are Michigan, Indiana and Chicago. Several of the largest film libraries in the world are in this same geographical area. Many famous film-processing laboratories are located here also; and the consumption of film in this region reaches rather astronomical figures.

Another index of the motion-picture and television activity in this central part of our continent is that two-day Regional Meetings held in recent years in St. Paul, in Ames, Iowa, and in Detroit have each drawn upwards of 200 members.

(President Kreuzer here described the Convention's excellent Equipment Exhibit and invited inspection of the many new items. The next section of his speech reports on the progress of the Society and activities of members during the year.)

Since our last meeting, Ed Warnecke and the Membership Committee have been as busy as usual so that our membership now stands at the peak figure of 6500. Reid Ray, Chairman of the Sustaining Membership Committee, and members of the Committee have increased Sustaining Members to a total of 117. Interest in Sustaining Memberships is increasing in the international field. This seems to be but a sign of the times and reflects the international activity of some of our members. For example, two of our members, Axel Jensen, our Engineering Vice-President, newly Knighted by the King of Denmark, and C. B. Mayer of London, formerly the European Advisory Committee Chairman, attended the international meeting in the radio and television field (known as C.C.I.R.) held this summer in Leningrad. At Harrogate, Great Britain, the International Standards Organization held their meeting this summer and your Society was well represented by a committee under the Chairmanship of Deane White. Again, only a few weeks ago, one or our members and a frequent exhibitor at our equipment exhibits, Joe Tanney, read two papers at the meeting of the Italian counterpart of our Society at their convention in Turin, Italy. Such activity bids well to expand interest in both the Miami Convention next Spring and the Toronto Convention in the Spring of 1961, both of which have international aspects.

As a further indication of the expansion of our Society's activities, you will be pleased to learn that at the midsummer meeting of the Board of Governors official approval was voted unanimously for the establishment of an Engineering Committee on Video-Tape Recording. This Committee is charged with proposing standards and good engineering practices for the construction, adjustment, operation and measurement of video-tape recording and reproducing equipment and for those video-tape dimensions or other characteristics which affect performance and interchangeability. This important new Committee is under the Chairmanship of Howard A. Chinn of CBS who has already given ample evidence that this will be an active and significant addition to our Society's Engineering Committees.

Among the many noteworthy activities of the Society, special mention should be made of the work of the Education Committee under the Chairmanship of John Frayne. Work directed on the West Coast by Ed Benham, Lorin Grignon and Sid Solow, and on the East Coast by Vice-Chairman Herb Barnett, J. W. Kaylor and Ed Schuller, has achieved outstanding success. A new series of lectures on Magnetic Video-Tape Recording of Television was introduced as part of the SMPTE-sponsored educational program in the University of California at Los Angeles. It is given in cooperation with the Engineering Extension Division and has been organized under Course Coordinator Ralph Lovell. The series of 20 lectures on Motion-Picture Sound Recording given in New York with the cooperation of New York University has been received with enthusiasm.

Another indication of the Society's progress is its publications program. Since the last report which was presented at the Los Angeles Convention, Volume No. 6 in the High-Speed Photography reprint series has been published, receiving the critical acclaim accorded the earlier volumes in the series. A new and up-to-date edition of the booklet "Wide-Screen Motion Pictures" will soon be published. Also, a new edition of the Society's "Television Bibliography" is being prepared to list all television papers in the *Journal* since 1940.

As I mentioned before, a meeting in Detroit is in the heart of a region famous for educational, industrial, and, more recently, television film production. In this connection, it is important to note that there are now 31 TV stations in the U.S.A. devoted exclusively to educational purposes. Five of these stations are broadcasting Junior College level courses.

The Dark Side of the Moon — Predictions

New as some of these applications for film and television techniques may be, it would appear that scarcely a month passes without some new challenge of technical interest to our Society. Possibly latest among these is the whole new frontier of space photography. Much of the exploration into space will require documentation by photographs. Who has seen in clear detail the surface of the moon or our planets as we shall see them from photographs made in outer space? What will we learn from a photograph of the dark side of the moon never seen before by the eye of man? How amidst what appears to be fifty million electron volt protons and other particles can we obtain these pictures? These are some of the challenges of the immediate future.

Thus, where once there were motion pictures alone, we have seen our Society's interests enlarged to include television, closed-circuit television, television films, photographic instrumentation, missile photography, more recently video-tape recording, and now, I predict, space photography. All of this practically in a decade.

I will not be heard again on an occasion like this. Thus, perhaps a closing comment may be in order. Let us continue to serve all parts of the industries with which we are associated and embrace new developments as they unfold, both individually and as a Society. If we do this, I am sure our Society will continue to go forward.

Motion Picture Engineers.

place just twenty years ago, in October of 1938.

Education — A New Era Begins

By MAURICE B. MITCHELL

(This is an abridgment of the October 20 Get-Together Luncheon Address delivered by Mr. Mitchell, who is President of Encyclopaedia Britannica Films Inc. Mr. Mitchell's stirring speech, which culminated with the hope that there is "good news in damnation," challenged the SMPTE to play a large part in the new era of education.)

WE HAVE all heard what Leon Beloit, the French philosopher, once called "the good news of damnation." It was his conviction that Man never found his utmost resources, never exerted himself to the fullest extent of his capabilities, until he literally felt the hot breath of hell's fire on the back of his neck. . . .

Teachers and school officials of our country remind us that they lack vital resources. . . . My associates at the Massachusetts Institute of Technology tell me that in the 28,000 high schools of the United States today there are probably no more than 11,000 adequately prepared physics teachers, and no more than 3,000 of these are first-rate.

We are hearing good news of damnation from industry. We have stepped across the threshold of a technological revolution. There is no road back. Every businessman knows that to preserve and advance the technology he must find trained manpower. His only resources are our schools, colleges and universities.

The Communication Revolution

Another revolution of our times is the communications revolution which will change the classroom of tomorrow.

Audio-Visual education began in 1928 in the Paramount Theater in New York City. . . (with) Al Jolson singing "Mammy" in the first sound picture ever made. This spectacle opened the way for educators handicapped by apparently insoluble problems in communication and education.

One was verbalism. Another was finding a device for giving common experience to the people who sit in a classroom. The teacher faces an almost insurmountable problem in communicating to different levels of perception. In films giving all students experiences in common, the teacher has found for the first time a device for establishing this precious uniform background.

Films make other unique contributions. A child in Cleveland can sit down in the home of a Chinese child, etc. (Here, Mr. Mitchell presented a detailed outline of the possibilities with film — how films take man out of his environment, back in time and into time compressed and expanded, into the most immense or minute spaces and inside man or matter, and to observe energy.)

The First Complete Course

Our primary concept in the development of audio-visual techniques was to help teachers overcome old limitations. In recent months we have gone far beyond that.

Working with the National Academy of Sciences in response to the shortage of physics teachers, we completed and delivered to the schools an introductory course in physics for senior high school or freshman college students. It is the first complete course in the American curriculum ever recorded entirely on sound motion-picture film. The National Academy of Sciences told us the best qualified teacher in the field of physics teaching was Harvey White of the University of California at Berkeley. Under merciless white-hot lights and remorseless stares of motion-picture and television cameras, he taught the classic course in introductory physics for 162 consecutive days. With its one and three-quarter million feet, it may be the biggest single sound motion-picture project ever undertaken. Closed-circuit television brought the course to experimental groups of students with no teachers present.

Harvey White's course has been used in 400 American schools during the last school year — often in classrooms with no teachers.

At the end of the first semester, all 1587 students took an achievement test in physics. Results: Students taught by the faculty scored 66% and those taught by the film alone scored 72.2%.

In Cummings, Georgia, an eighth-grade boy has been placed in a senior class at Forsythe County High School to study physics by film. He is scoring in the top third of the class. This is of interest to those who have noted that Russian children begin physics in the sixth grade.

The Ten Years Ahead

We now have a team at the Massachusetts Institute of Technology who propose doing weird and wonderful things to the classical or traditional American high school physics curriculum represented by the course Dr. White put on film. It is their contention that physics, as we now teach it, has been outmoded since 1926!

This team of 90 physicists, exploring the far frontiers of this subject and talking a language few people can understand, literally tore the old physics course out by the roots. Their textbook is unlike anything physics teachers have ever seen. The laboratory equipment is made from Erector sets, old lumber, soda straws, coat checks, and used frozen orange juice cans — to name just a few of their improvisations. They would like to see the student make his apparatus with his own hands in his own home to enjoy what Robert Oppenheimer calls personal experience in the discovery of scientific principles. We are shooting 70 films which have no precedent in the entire audio-visual field, 70 new concepts fresh out of an atomic-energy-oriented world.

Yet, this isn't good enough. We are only doing in the audio-visual field what education has always done — taking the leavings of American technological development. The television set in the classroom is at best an adaptation of the set in the living room. It is not designed for classroom use; it does not function ideally as a classroom instrument. The sound motion-picture projector we use is a shrunken-down version of the big projector designed for motion-picture theaters. It hasn't radically changed in the last quarter-century. It is still a great, fat, hot, wheezing device which terrifies most school teachers of either sex. We are still making motion pictures on the same delicate, fragile acetate we made them on in the beginning, with its precision-punched sprocket holes and the delicate layers of chemicals on the top. We put the film in the can and it shrinks and stretches and liquefies and does all sorts of strange and mysterious things. It is still hand-processed in some kind of witch's brew in a dark room.

The Classroom of Tomorrow

Let me describe the classroom of tomorrow as it will be equipped for audio-visual education. It will be set up so the room can be effectively darkened. It will have no projector; it will use no film. There will be a sheet of glass in the front of the room, a part of the blackboard, on which the instructor can write in chalk. Next to it will be the telephone dial, and from the dial will hang a telephone book, and in that book a catalog of every audio-visual device, film and film strip that has been made. . . The instructor. . . .will look up the number of the film he wants, and dial it. The picture will appear instantly on the screen, flown through space by microwave relay to the saucer on the roof, and a stream of electrons will paint it on the screen. The things I am describing are in the present state

of the art. No inventions, no breakthroughs are required. We could do it now. All we need is the profound conviction that it is this kind of teaching tool we want the nation's classrooms to have.

The right film, the right place, the right time. . . ! Institutions where effective and advanced use of films is now made include the huge library in Georgia which has the largest single collection of educational motion pictures in the United States. It sends out 200,000 classroom films a year to Georgia schools, postage paid both ways. A library in the Province of Ontario had classroom audiences running to 10,300,000 students last year. The Morton Township High School in Cicero, Ill., uses 60 sound motion pictures a day.

The Soviet Accomplishment

I have sketched. . .some implications in the communications revolution for education. We are only on the starting line. Many things we have come to accept as routine in education will change radically.

Douglas Johnston of the London County Council, that civic board which runs the schools in the capital city of Great Britain, took a team of British teachers for a hard look at the schools behind the Iron Curtain. He described the average Russian classroom in a school of 562 students. The teacher stands at the front of the room. In front of him is a control panel of switches. He darkens the room by remote control. He activates a projector threaded with films from his own private film library assigned to his subject area and kept in his school building. He can start and stop the projector. He can run it back and start over. He can knock out the soundtrack and let a student narrate the film to demonstrate his understanding of the concepts. If he wishes, he can project, simultaneously on the same screen, film strips from a separate film-strip projector. He also has an overhead projector. What was found in the science classrooms was also found in the geography and history classrooms.

There is tremendous use made of the tape recorder in the Soviet Union for the study of languages. I am told there are 43,000 teachers of English in the Soviet Union. I am further told that not a single institution of higher learning in Ohio teaches Russian. And I am told at MIT that 10 years from today a student in the sciences who has Russian and English at his command will hold the key to 80% of the scientific literature of his time.

Have We Any Option?

Technological and communications revolutions have a way of destroying the options of those who live through them. The businessman in the buggy-whip business had no option. He adapted to the technology of his times, or he was dead. Perhaps in education the same holds true. What option do we have to ignore the products of our communications revolution? If we do, what price will we pay? What will be the outcome of the desperate struggle for men's minds? Is all this just news of damnation — or can it be, if we will make it so, *the good news of damnation?* This is the challenge.

It comes at a difficult time. We haven't the money to build the buildings, to train and pay the new teachers we need to absorb the flood of population pouring into our schools. How we solve these problems may determine how we live a generation or two from now.

Edit. Note: The above is a severe abridgment of Mr. Mitchell's substantial address. Full details and supporting argument have been published by Fenn College. Copies of the ten-page reprint are available at no charge from Society Headquarters as long as the modest supply lasts.

The Adventure of Technicolor

By HERBERT T. KALMUS

First I want to express my deep appreciation to the Board of Governors, to the Honorary Membership Committee and to its Chairman, Dr. D. R. White, for having conferred upon me the grade of Honorary Member of the Society. I am greatly moved by this high honor.

I wrote an article "Technicolor Adventures in Cinemaland" which I submitted to the Detroit meeting of the Society of Motion Picture Engineers on October 28, 1938, almost exactly twenty years ago. An adventure may be defined as a remarkable experience, usually accompanied with some risks. That was a fair characterization of the history of Technicolor during the twenty years prior to the date of that paper in 1938 and has been equally characteristic of Technicolor during the twenty years since that date.

I will indicate briefly some of the similarities, some of the differences and one common denominator among these adventures. I think it will follow that this honor must be shared with many members of the Technicolor staff.

At the beginning of Technicolor there were no theatrical motion pictures in color so the field of approach was open. A decision had to be made between attacking the problems through a multilayer method of photography or separate negatives and between multilayer and imbibition printing. In the early years the second of these alternatives was adopted in each case. Today practically all motion-picture photography is upon multilayer negative, but there is still the choice between multilayer prints or imbibition prints. The areas of preference or advantage for each of these systems can be enumerated and it is the aim of Technicolor to serve the industry with one or the other or both as best suits the industry's requirements.

In 1924 Famous Players Lasky Corporation, predecessor of Paramount Pictures Inc., produced a picture called *Wanderer of the Wasteland.* This was the first important adventure of the Technicolor process under normal motion-picture studio and exterior conditions although earlier pictures had been made as demonstrations by Technicolor Corp. This picture was reasonably successful but the industry was uninterested because the price of prints at that time was 15 cents a foot and because the negative had to be sent to Boston for development and for making of rush prints. How conditions have changed since then! Productions may now be photographed in any part of the world for eventual printing in natural color without being impractically far from a Technicolor laboratory in Hollywood, London, Paris or Rome; and the price of 35mm release prints had gradually been reduced from 15 cents a foot until now the base price is about $5\frac{3}{4}$ cents a foot.

Another early adventure of Technicolor occurrred when Douglas Fairbanks produced *The Black Pirate.* The main argument against color pictures at that time was that they tired and distracted the eye, took attention away from the acting and facial expressions and blurred and confused the action. Fairbanks contended that these fundamental views persisted because no one had taken the trouble to dissipate them. He could not imagine piracy without color. *The Black Pirate* was released through United Artists in 1925. So far as audience reaction, press reviews and boxoffice receipts were concerned, it was a triumph from the start but for Technicolor it was a terrible

This response was written by Dr. Kalmus for the occasion at which he was made an Honorary Member of the Society, October 21, 1958.

headache. Technicolor prints at that time were made by imbibing dyes into relief images, two of which were cemented or welded together back to back, thus creating a double-coated imbibition print. These double-coated films in the field would buckle first one way and then another so that focus was uncontrollable.

Technicolor needed a single-coated imbibition process. This development required a series of inventions by the Technicolor Research Laboratory and many years of patient application with manufacturing equipment.

By the year 1929 Technicolor had spent about $3 million for cameras, printers, imbibition machines and research. The encouragement from the industry was still sporadic so Technicolor decided to produce a few short subjects and later a feature-length picture to prove to the producers that the Technicolor process was eminently practical and that the problems of light requirements for color, color composition and additional time of shooting were readily surmountable. We kept careful records of time and cost schedules and by freely discusssing these we dissipated much of the prevailing misinformation.

Then came the rush. Warner's *On With the Show*, the first all-talking Technicolor feature, was followed by Goldwyn's *Whoopee*, with Eddie Cantor, and then there was such a rush for Technicolor cameras that they were hardly allowed to cool off. The prints were necessarily made in a hurry to meet the demand. And all of this with a two component process!

In 1938 I wrote:

"This premature rush to color was doomed to failure, if for no other reason, because the Technicolor process was then a two-color process. In the last analysis we are creating and selling entertainment. The play is the thing. You cannot make a poor story into a good one by sound, by color, or by any other device or embellishment. But you can make a good story better. Broadway has a terrible struggle each season to find good stories or plays for a dozen successes. Hollywood is trying to find over five hundred. They don't exist. The industry needs all the help it can get, all the showmanship it can summon — it needed sound; it needs color.

"But color must be good enough and cheap enough. The old two-component Technicolor was neither — hence it failed, but it was a necessary step to present-day Technicolor."

Through all this, Technicolor persevered in its development and research work and completed the building of its first three-component camera in 1932. From then on Technicolor photographed and printed a series of important pictures made by every major producer in the business, including the Whitney-Selznick great *Gone With the Wind*. Every step of the way had to be supported with tests and proofs and with an ever-improving quality and reduction in price.

All these were early problems which constituted the Technicolor adventures of the twenty years, ended in 1938. Since then Technicolor has been in the midst of new adventures just as drastic, of an entirely different nature, but with something in common.

In the year 1952 Merian Cooper, representing Cinerama, appealed to Technicolor for technical cooperation and help. It was more in the nature of a rescue and the circumstances were desperate. Photography had been accomplished all over the world. The negative was there, but who could make prints to be handled by the three projectors in the theater so that they would screen without excessive jiggle among the three components, would be in sharp focus, of proper photographic quality, delivered on time and, above all things, would put the audience into the picture, which is the essence of Cinerama? That was accomplished and we had the first Cinerama picture *This is Cinerama*.

Then in 1953 came Spyros Skouras and Darryl Zanuck with CinemaScope. They had, no doubt, been inspired by the large screen and other effects of Cinerama and they had completed the photography of the first CinemaScope picture, *The Robe*. But the problem was to make prints to meet the pressing schedules and of proper quality. Again, Technicolor came to the rescue.

As another instance of the relatively recent problem, we have the inventions and developments that finally became VistaVision. Paramount and Technicolor were interested to cooperate in this because it employed only standard 35mm film and was capable of giving most, if not all, the advantages that were being sought by the industry with increased area negatives. That was a development in which Technicolor played and still plays a leading part.

Much more recently we have Todd-AO, another daring adventure of the large-area negative type, this time employing 65mm negative. Again, with the picture finished, they were confronted with the problem of obtaining prints that were suitable on the one hand for road shows on terrifically large screens or, on the other hand, for general distribution with standard 35mm film. Technicolor responded successfully to the urgent call of Mr. Todd for cooperation, and provided prints of *Around the World in Eighty Days*.

Within the last two years Technicolor has evolved and has offered to the motion-picture industry a multipurpose system of photography which it has introduced under the name Technirama. This system, like VistaVision, employs two frames of standard 35mm negative and in addition introduces an anamorphic squeeze in the camera so designed that from this Technirama negative every kind of release print can be made. This flexibility is due to an anamorphic squeeze or unsqueeze in one or more of: the camera, the printer or the projector, together with the possibilities introduced by the Technicolor imbibition method.

With Technirama one negative is provided from which the following release prints may be made:

(a) Technirama double-frame anamorphic prints, either imbibition or color positive.

(b) 70mm color positive prints for use in Todd-AO and other projectors.

(c) 35mm CinemaScope-type imbibition prints.

(d) 35mm "flat" imbibition prints.

(e) 16mm imbibition prints.

Prints for road shows can be made by Technicolor processes whether the photography is by 65mm Todd-AO or by M-G-M camera 65 or by Technicolor Technirama.

Generally, where various sizes and shapes of negative are employed and various sizes and shapes of screen picture are required, a process like Technicolor imbibition which employs projection printing yields the most satisfactory results. With contact printing, the employment of a dupe negative would be required with its attendant degradation of quality. In the Technicolor imbibition process matrices are made by projection printing and from each matrix an estimated average of 50 prints may be produced. The Technicolor imbibition process uses the negative sparingly, perhaps ten or fifteen times to manufacture 700 prints, whereas for other processes, the negative is used each time a print is made unless dupe negatives are employed.

The common denominator of all these processes and steps in which Technicolor has been playing so important a part during recent years is the great flexibility of the imbibition process which employs optical printing and matrices.

This brief review will indicate that the problems in which Technicolor has more recently become involved, aiming to improve the quality of motion-picture entertainment and to lower its cost, while different, are no less important than those with which it was confronted at the time it first introduced color to the screen.

But also, and more pertinent to this occasion since this honor has been given me (and I quote) "for distinguished contribution in the field of color photography for motion pictures," I want it to be clear that credit for these contributions to a large extent belongs to past and present members of the staff of Technicolor Corporation.

news and reports

85th Convention—Miami

Films and Television for International Communication as a theme for the Society's Spring Convention, May 4–8, has brought many papers proffered early for the Program. The deadline is February 19 for Author Forms to reach the Program Chairman, from authors or Topic Chairmen. Complete details are in the November *Journal*, p. 776, which lists Topic Chairmen who will be most immediately helpful. General information and all the forms are available from Society headquarters or from the 85th Program Chairman, *Garland C. Misener*, 1905 Fairview Ave., N.E., Washington 2, D.C.

Hotel Reservations

George Gill, Hotel Arrangements Chairman, reports that we may be running into a shortage of rooms at the Fontainebleau compared with the number usually available at convention hotels in other cities. For this reason, it is urged that those who want to be sure of getting accommodation in the Fontainebleau send in their reservations to the hotel without delay. The Newsletter printed on the reverse of the Section Meeting Notices for January will include a reservation blank for members' convenience in doing this. Those not using the blank should be sure to mention, in their letter to the hotel, the fact that they will be attending the SMPTE convention.

Rates at the Fontainebleau are $14, $16, $18 and $22 per day for room and bath, for either single or double occupancy. A one-bedroom suite is $45, and two-bedroom suites are available at $70 and $80, per day. A $25 deposit must accompany all reservations; in the event accommodation must be cancelled, this deposit will be returnable provided the cancellation is made at least 48 hours prior to the date of the reservation.

Equipment Exhibit

Arrangements for the physical layout of the International Exhibit, which have been somewhat contingent on the hotel's plans for reconstructing its convention facilities, have now been firmed up. The Grand Gallerie, lying immediately adjacent to the auditorium where the technical sessions are to be held, and en route from the registration area to the sessions, will provide compact and unified accommodation for approximately 50 booths.

Response to the initial publicity has been coming in to an extent that indicates a sell-out. European and Japanese manufacturers have already sent inquiries to headquarters, and the first truly international display of strictly professional motion-picture and television equipment ever to be assembled in this country is now definitely in the making. This should be a unique opportunity for members to see the latest advances made by the industry in all parts of the world.

Booth assignments will be made early in January. Companies wishing to take part should contact, as soon as possible, the Exhibit Chairman, John B. Olsson, c/o Beattie-Coleman, Inc., 1000 N. Olive St., Anaheim, Calif., or notify Denis Courtney at Society headquarters. Order forms, prices, and complete information on how to participate will be sent on request.

The 84th Convention, Detroit

Built around the theme of *Films and Television in Industry and Education*, the 84th Convention was an inspiring demonstration of the Society's ability to adapt, to grow, to keep pace with the tremendous changes taking place today and to anticipate the technological and social developments of tomorrow. The word "revolution" both stated and implied seemed to be the underlying motif of many papers on the general subjects of education, new techniques, applications and developments.

The keynote speech on the New Era in Education, delivered by Maurice B. Mitchell, made reference to what he called "good news of damnation." He explained the apparent paradox by pointing out that the greatest achievements in many fields of endeavor have come about as a result of fearful events and disastrous trends forcing re-evaluations and the finding of new solutions to old problems and adequate methods of dealing with the new. (Excerpts from Mr. Mitchell's speech appear on earlier pages of this *Journal*.)

The entire Papers Program of 82 papers was outstanding for its timeliness and for the fine manner in which the sessions were run. Such an achievement is a tribute to the devoted efforts of Program Chairman C. E. Heppberger. H. W. Kinzle was Associate Program Chairman.

The "new look" was predominant in the sessions on nontheatrical films. The Tuesday Morning Session took "A New Look at Film Techniques for Education" and the Tuesday Afternoon Session was on the "New Look" at film for business.

Topic Chairman for Nontheatrical Production and Techniques, Industrial Phase, was John Flory who has long been recognized as an authority on nontheatrical films. His devoted work for the Convention resulted in a substantial assemblage of papers. Equally impressive were the papers on the University Phase for which O. Stephen Knudsen was chairman.

The six papers presented at the Education Session dealt in a realistic fashion with new teaching techniques, conveying a total impression of recognition of a crisis in education and a practical approach to new problems. A paper by Sol Roshal of Los Angeles on "New Perspectives for the Use of Film in Education" warned that in order to meet educational requirements film production must go in new directions. He advised the production of short, specific films for flexibility, as well as production of more lengthy films for entire classroom sessions.

An interesting account of the new studio at Brigham Young University, Provo, Utah, was authored by Robert W. Stum and R. Irwin Goodman, and delivered by Herbert E. Farmer.

The growing importance to industry of nontheatrical films was ably brought out by six papers presented at the Session on Business. A paper by John Flory and Thomas W. Hope, "Analysis of Growing Business Film Usage," discussed the areas in business and industry where films are being effectively used. A paper by E. H. Plant, L. W. Jenkins and J. B. DeWitt of Eastman Kodak Co. made the interesting observation that the camera is used as a "thinking tool" in photographing plant operations.

The Monday Evening Session on Documentary and Educational Film Production had an exciting quality both in subject matter and presentation. The presentation by William R. Witherell, Jr., of Video Films, Detroit, on creativity and flexibility in the use of unusual or substandard equipment had the happily chosen title of "Milking the Oddball Camera." Geoffrey T. C. Mangin, Central African Film Unit, Salisbury, S. Rhodesia, Africa, described the organizational and technical problems of producing films for local demands.

A description of the work at Bob Jones University, Greenville, S. C., noted for the professional quality of its films and training, was presented by Mrs. Gilbert Stenholm in a paper, "The Unusual Films Motion-Picture Production and Training Unit at Bob Jones University."

An especially stimulating exchange of ideas and information took place Monday afternoon following the annual Business Meeting. The Symposium on 16mm Color Intermediate Negative/Positive Release Printing, under the guidance of Robert A. Colburn of Geo. W. Colburn Laboratories Inc., Chicago, afforded an interchange of laboratory methods used by leading Midwest laboratories, with representatives of each laboratory describing its processes and special equipment.

One of the newest of the "new looks" is international television. Its potentialities were dramatized in the Thursday Afternoon Session on "Machine Language Transla-

Maurice B. Mitchell, President of Encyclopaedia Britannica Films Inc., speaking on the New Era in Education at the Get-Together Luncheon of the 84th Convention at the Sheraton-Cadillac Hotel, Detroit.

tion and International Television." Topic Chairman for papers on this subject was Ellis W. D'Arcy whose contagious enthusiasm has sparked awareness of its importance. A paper by Ed Dyke, Page Communications Engineers Inc., Washington, D.C., spoke of "strides being made toward realizing the dream of international television."

Topic Chairman for papers on the subject of Color Photography was John P. Breeden, Jr. Richard O. Painter was Topic Chairman for Instrumentation and High-Speed Photography papers. The three papers in a Standardization Session organized by A. C. Robertson are published in this issue of the *Journal*. Papers on Sound Recording and Reproduction were in the province of Topic Chairman Gordon L. Ellsworth.

Wednesday morning and afternoon were devoted to television with the "new look" emphasized in the afternoon Session on "A New Look at Film Techniques in Television." A paper by David W. Johnson, Univ. of Southern Calif., described certain unique production problems and flexibility requirements for educational films.

Topic Chairmen for Television Concepts and Practices were: Edgar J. Love, Commercial and Industrial; Allan M. DeLand, Educational; Film Techniques, Rodger J. Ross. Papers on Studio Lighting and Practices were under the aegis of Dennis Gillson. Topic Chairman for Theater Projection Practices was Frank H. Riffle.

A fascinating "travel-electronics-log" was presented by Engineering Vice-President Axel G. Jensen at the Session on Machine Language Translation and International Television in which he recounted his impressions during two trips to Russia. In a paper "Impressions of Electronics in Russia," he described the development and progress of television in the Soviet Union in 1957 and 1958, with emphasis on color television. He illustrated his talk with Kodachrome slides of photographs taken in Moscow and Leningrad.

Films at the Convention

As papers, parts of papers and as short-subject films introducing sessions, motion pictures were a rewarding part of the Convention.

Dana Manning of the Jam Handy Organization selected a group of 13 short subjects shown at the beginning of the various sessions for the edification and amusement of the audience. The films were all scheduled and shown in the printed Program, except for one transposition later for convenience of projection, and projection of two additional films.

In the Beginning, a Socony-Mobiloil offering produced by Cate & McGlone, conveyed an awe-inspiring view of the turbulent and monstrous youth of the Earth as revealed by the Grand Canyon of the Colorado. *American Look* produced by the Jam Handy Organization was a rich and sustained presentation of design in America today including auto designs.

An especially delightful short subject, *Le Merle* (*The Blackbird*), produced by the National Film Board of Canada, was a prizewinner from the Short Film Competition at the Brussels World Film Festival.

Other short subjects from the consistently interesting and well chosen program included *Wings of Austria*, Dick Durrance Productions; *Equation for Progress*, MPO Productions Inc.; *Navy Wings of Gold*, Jam Handy Organization; *Melbourne Olympic Games*, Australian Photography edited by Jam Handy Organization; *Knowing's Not Enough*, Wilding Picture Productions Inc.; *The Petrified River*, MPO Productions Inc.; and *Color and Texture in Aluminum Finishes*, On Film Inc. *Dial S for Service* was produced by Henry Strauss for Pan American World Airways as a part of its very extensive personnel training program.

Space Pioneer, about the satellite, was especially obtained and shown late in the week. It is a 10-minute film in black-and-white, a Hearst Metronome production for the U.S. Information Agency. Also shown one afternoon was the documentary *Tragedy U.S.A.* produced by Universal International Pictures.

The Convention audience particularly benefited from picture and sound demonstrations with such papers as "Milking the Oddball Camera," by William R. Witherell, Jr., who gave many film examples of his cases of improvisation. With the paper "Catching Bank Robbers With Cameras" by Alfred Jenkins, the audience saw film and was convinced—just as one of the robbers had been when he saw himself in robber action on television in a bar in the next state where he was the evening after the robbery. The robber was convinced and turned in his tools. G. T. C. Mangin showed films made by his Central African Film Unit.

Wine of Morning, a full-length feature in color made by Unusual Films, a department of Bob Jones University, closed the Monday Evening Session which had included a paper by Mrs. Gilbert Stenholm who directed and produced the film. Mrs. Stenholm described the extensive and very well equipped film production and training unit at Bob Jones University.

"The TV Workshop: A Unique Agency Client Service" was presented as a film by Warren G. Smith of J. Walter Thompson Co. "A Scientific Approach to Foreign-Language Dubbing" was a demonstration film provided by De Lane Lea Processes Ltd. of London.

Two sound papers effectively presented with examples were: "A New Approach to Magnetic Half-Striping of Optical Tracks" by Maxwell A. Kerr; and "A Multichannel Selective Program Repeater Utilizing the New Mackenzie Continuous-Loop ¼-in. Magnetic Tape Magazine" by Louis G. Mackenzie.

The high-speed photography presentations benefited by films, chiefly in color, exemplifying cinemicrography and cinemacrography for various purposes and with varying illumination and techniques.

Members and guests view part of the Equipment Exhibit displayed October 20–24 at the 84th Convention in Detroit.

GM Technical Center and Photographic Division

Special arrangements were made for members to visit General Motors Technical Research Center. On Friday morning, the General Motors Photographic Division was host to the Society with the papers session held in their fine theater and sound stage. With a joint session split between two general subjects, there was a natural opportunity for members to inspect the audio-visual production facilities housed in two complete floors of the large building. Another complete floor is devoted to still photography. The Society enjoyed the hospitality of Philip Filmer, Director, and Kenneth C. Dick, Assistant Director, and the opportunity to observe at first hand the numerous and varied photographic operations carried on within the Center. Each area attracted specially interested observers. The Color Laboratory, established more than a quarter of a century ago, was the first operation of its kind in the Detroit area. The present laboratory is staffed and equipped to handle all known color processes. The laboratory displays with pride its "jumbo" transparencies, one of which is 20 ft. long and made in seven sections.

The Audio-Visual Department attracted considerable interest, with James W. Bostwick, its manager, making full inspection visits generously available. It is completely equipped for handling every phase of audio-visual production, including a carpentry shop for set construction and film library of historical and other "stock shots."

Equipment Exhibit

Predictions that Detroit would welcome the unusual opportunity of seeing professional motion-picture and television equipment assembled in this center of industrial and commercial film activity were amply justified. Conveniently compact, and situated in an ideal location next to both the registration area and the sessions auditorium, the Exhibit was briskly busy all week long and exhibitors reported a high degree of interested attention to the many new devices on display. Every booth in the room was occupied, and the range of equipment shown by the participating companies ran all the way from lenses to huge processing machines.

Booth holders at the Exhibit were:

- Animation Equipment Corp.
- Bell & Howell Co.
- Camera Equipment Co.
- Canadian Applied Research Ltd.
- Andre Debrie Mfg. Corp.
- Electronic Systems, Inc.
- Florman & Babb, Inc.
- Harwald Co.
- Karl Heitz, Inc.
- HiSpeed Equipment, Inc.
- Hollywood Film Co.
- Kling Photo Corp.
- Lipsner-Smith Corp.
- Macbeth Instrument Corp.
- Motion Picture Printing Equipment Co.
- Neumade Products Corp.
- Precision Laboratories
- Reevesound Co.
- Ro-Nan Plastic & Mfg. Co.
- S.O.S. Cinema Supply Corp.
- Unicorn Engineering Corp.
- Westrex Corp.
- Wollensak Optical Co.

Great credit for this successful show is due to Ray Balousek who, in addition to his many duties as Registration Chairman, assumed the responsibility for all the preparatory work involved in getting the Exhibit organized, handled the booth orders, and was tirelessly helpful in supervising its smooth running during the week. The Society is greatly in his debt.

Comments gathered from exhibitors at the end of the week indicated that many of them will be back next spring for the International Equipment Exhibit in Miami. With many foreign companies on hand for the first time, this is expected to be the biggest and best attended show the Society has ever organized.

The Coffee Club, transient or abiding headquarters for many members, was provided by courtesy of Jack A. Frost, with Miss E. A. (Susie) Taube especially supervising the hospitality for Convention guests.

Local Arrangements

A successful Convention is produced within a structure of a myriad of large and small details, neglect of any one of which may seriously mar the week's show. Many of these details fall within the province of the Local Arrangements Chairman. Local arrangements for the 84th Convention were under the capable supervision of James W. Bostwick who, we may assume, along with the other devoted behind-the-scenes workers, drew the proverbial breath of relief as all possible crises and disasters were by-passed or nipped in the bud.

The very important services of Public Address and Recording were the respon-

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sibility of N. D. Reiss of Reiss Public Address Systems. Rod Gates of General Motors Photographic was at the hotel to help set up the system and was on duty on Monday until afternoon when Harrison Engle of Wayne University took over on through the evening. He was assisted by Floyd Churchill of Jam Handy Organization Inc., and Marty Shore of Wilding Picture Productions, both members of IATSE Local 199. Others manning the system during the week were John Holowathy of Ford Engineering, Glen Fredericks of Ford Communications, Stan Cain of Wayne University, Chuck Lewis of Ford Communications, and Charles Nairn of Wayne University. Rod Gates on his home ground at General Motors Photographic was responsible again on Friday morning.

Special credit is due Projection Chairman John A. Campbell who was responsible for the well-coordinated and smoothly running program. Many hours of difficult projection requirements were met by Floyd Churchill of the Jam Handy Organization and Marty Shore of Wilding Picture Productions, both from IATSE Local 199. Alan F. Byrnes of Jam Handy also helped, especially in packing up the show.

In addition to his duties as Exhibit Chairman, Ray A. Balousek was in charge of Registration. The task of Auditor was faithfully accomplished by William B. McLaren. The complexities of Hotel Arrangements were resolved by Clifford Hanna. E. S. Purrington was in charge of Transportation. The role of guide, mentor and friend is required of the Hospitality Chairman, which was the responsibility of Sherman Willson. Larry Silverman of Wayne University was on hand to see that accurate information and friendly greetings were offered members and guests. Jerome Diebold was in charge of Membership. The exacting chore of Publicity was undertaken by Henry Zuidema, and under his guidance publicity activities covered the highlights smoothly and effectively. Luncheon and Awards Arrangements were the responsibility of T. P. Marker whose efforts contributed to the impressiveness of the Awards Ceremony and the enjoyment of the Get-Together Luncheon. Michael Omalev was Banquet Chairman. Also contributing to the success of a memorable Convention were Administrative Assistants Kenneth Mason and W. T. Strother.

The Ladies Program was, perhaps, more heavily weighted on the side of instruction and less on the "just fun" side than usual. The visit to the GM styling studios of General Motors Technical Research Center was an exciting and informative experience, with emphasis on the future. History was illustrated by the Henry Ford collection at Greenfield Village, and contemporary trends in art and architecture could be observed by visitors to the famous Cranbrook School. The luncheon and fashion show, Friday, at Devon Gables, rounded out a most successful program. Mrs. Raymond A. Balousek, Mrs. James W. Bostwick and Mrs. Michael Omalev were in charge.

Society Awards

Among the Society's most honored traditions is the Awards Session which is a part of each Fall Convention. On Tuesday evening, October 21, the Society honored those of its members who had been selected by the appropriate committees as deserving of recognition for outstanding achievements which have furthered the progress of the industry. Among the highlights of the ceremony was the bestowal of two separate Awards, the Journal Award and the Samuel L. Warner Memorial Award, upon George Lewin, whose contributions to the sound recording field met the exacting standards of each committee.

Honorary Member

The Award of Honorary Membership was granted Dr. Herbert T. Kalmus. The honor was bestowed in absentia and was accepted for Dr. Kalmus by S. E Howse. The citation, prepared by the Honorary Membership Committee under the Chairmanship of Deane R. White to accompany the Award, stated:

Dr. Herbert T. Kalmus, more than any other person, has been the dynamic influence which has brought color pictures to the motion-picture theater. As the founder and guiding hand of the Technicolor Corporation, he sought out and developed a commercially practical system of color photography which has supplied the great majority of motion pictures in color over the past thirty years.

It is interesting to note that just twenty years ago, in this same city, the Society awarded Dr. Kalmus its Progress Medal. In the citation for that award, Mr. G. F. Rackett included the following comments:

"Dr. Kalmus had an ideal, and, more im-

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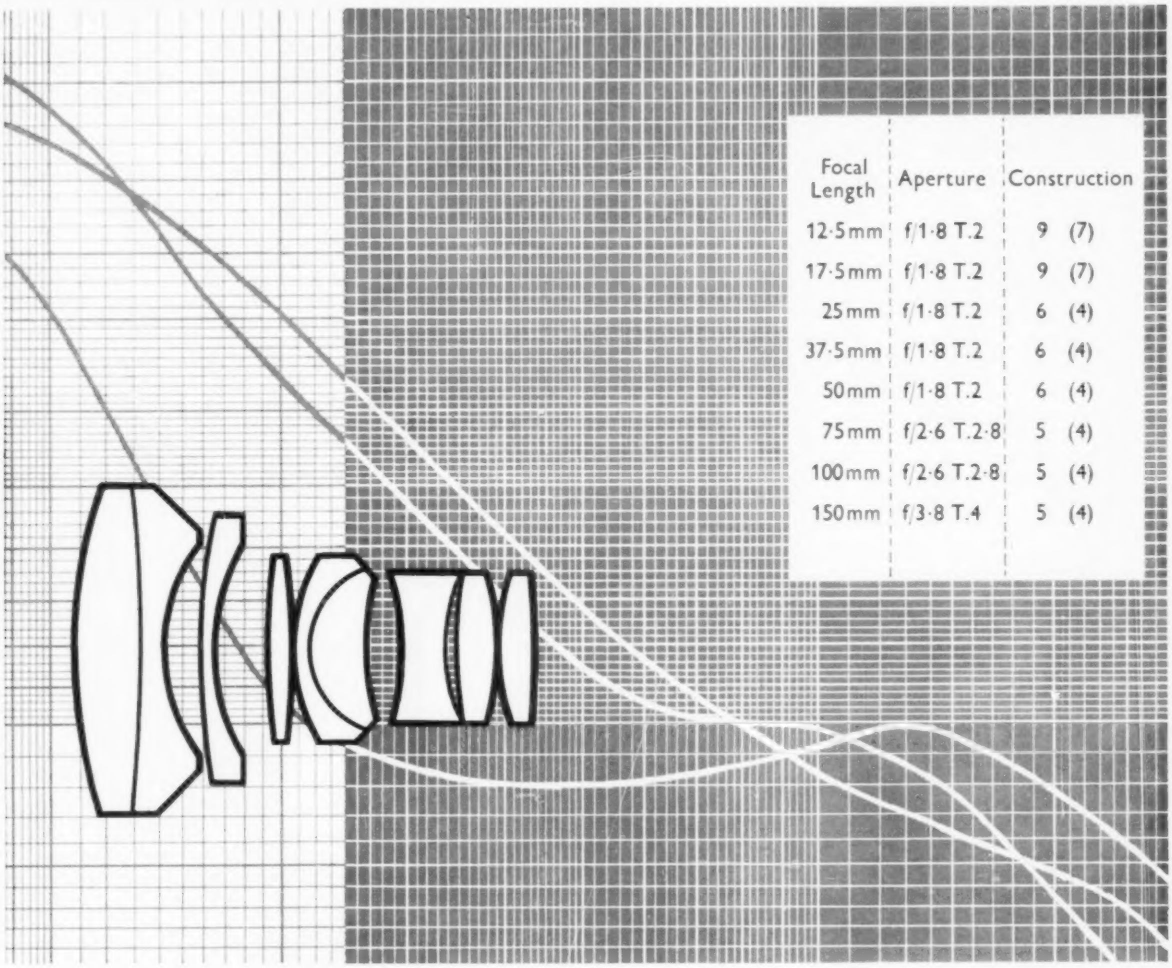

Focal Length	Aperture	Construction
12·5mm	f/1·8 T.2	9 (7)
17·5mm	f/1·8 T.2	9 (7)
25mm	f/1·8 T.2	6 (4)
37·5mm	f/1·8 T.2	6 (4)
50mm	f/1·8 T.2	6 (4)
75mm	f/2·6 T.2·8	5 (4)
100mm	f/2·6 T.2·8	5 (4)
150mm	f/3·8 T.4	5 (4)

1. Eight lenses with 3 types of construction.
2. Specifically designed for the requirements of professional 16mm motion picture photography.
3. Calibrated in T stops and F stops.
4. Available as unmounted lenses for use with Mitchell 16mm motion picture camera and in Taylor-Hobson designed mounts for 16mm Arriflex camera. Focusing "C" mounts will be available in the near future.
5. Superb color correction.
6. All focal lengths designed to take fullest advantages of Lanthanum and rare earth glasses.

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Presentation of Herbert T. Kalmus Gold Medal to Merle L. Dundon, at left, by SMPTE President Kreuzer. The Citation was read by Herman H. Duerr (at right), Chairman of the Herbert T. Kalmus Gold Medal Award Committee.

portantly, the ability to analyze the technical aspects of the problem, to develop and supervise a staff of scientists, experimenters, and engineers exploring and solving these problems in a well conceived and directed plan, traveling always toward the ultimate goal of natural color in a form practical for use in the motion-picture theater. It is seldom in the annals of technical development that the ability to direct the business, economic and technical aspects of a highly specialized enterprise have been successfully carried out by a scientist whose ability reached equally into the fields of technology, economics and business."

The twenty years since these statements were made have continued to bear witness to Mr. Rackett's statements. Continued improvements in Technicolor's imbibition process of making three-color prints have provided theatergoers with natural color of the highest quality.

The abilities which enabled Dr. Kalmus to foresee the possibilities of a successful color system and to lead his organization through the early uncertain years to success were due in part to his formal scholastic training and his early experiences in business. Dr. Kalmus was graduated from the Massachusetts Institute of Technology with the degree of Bachelor of Science in 1904. In 1907 he received the degree of Doctor of Philosophy at the University of Zurich. Following several years as research associate at MIT and a short period as professor of physics at Queen's College in Canada, he became a partner in the newly organized firm of consulting engineers of Kalmus, Comstock & Westcott, Inc. It was at this time, in 1916, that he first began active work on color photography, and organized the Technicolor Corporation.

Early Technicolor pictures were made by cementing together two film strips back to back, with dyed gelatin relief images on the outer surfaces. Later, by use of the Technicolor split-beam cameras for making two original negatives, and use of imbibition printing to provide a single image composite print with a silver soundtrack, the two-color imbibition process was developed. This was further developed to the three-color process by addition of a third film as a bipack in the split-beam cameras, and use of three matrix films for imbibition printing, with a light silver picture image and silver soundtrack.

Important as were the technical problems in the progress of Technicolor's growth, it was Dr. Kalmus' understanding of the economic problems and his creative business ability which enabled him to succeed in bringing full color to the theater many years before it otherwise would have been provided.

In conferring Honorary Membership to Dr. Herbert T. Kalmus, the Society of Motion Picture and Television Engineers welcomes a true pioneer whose contributions to the motion-picture industry have been unique and whose continued active interest is an inspiration to all who are associated with current motion-picture development.

Fellows

The following members were raised to the rank of Fellow. Certificates were presented by Dr. John G. Frayne, Past-President of the Society:

W. S. Ball	C. W. Hauge
P. M. Cowett	S. E. Howse
R. B. Dull	K. B. Lewis
L. G. Dunn	D. L. MacAdam
C. P. Ginsburg	H. W. Pangborn
T. B. Grenier	B. F. Perry
Louis Hagemeyer	Douglas Shearer
C. S. Stodter	

Journal Award

The Journal Award for 1958 was presented to George Lewin for his two papers on "The Infrared Transparency of Magnetic Tracks." Four other papers were chosen for Honorable Mention. Recipients of Honorable Mention and the papers are:

Willy Borberg for "Effect of Gate and Shutter Characteristics on Screen Image Quality"

Armin J. Hill for "Analysis of Background Process Screens"

Donald Kirk, Jr., for "Economic Consider-

Presentation of Journal Award to George Lewin, at left, by SMPTE President Barton Kreuzer. The Citation was read by Editorial Vice-President Glenn E. Matthews (center).

Presentation of David Sarnoff Gold Medal to Albert Rose, at right, by SMPTE President Kreuzer. Axel G. Jensen, Engineering Vice-President, at left, read the citation.

ations in Closed-Circuit Television System Design"

R. G. Neuhauser for "Black Level—The Lost Ingredient in Television-Picture Fidelity"

The following citation, accompanying the Journal Award, was read by Glenn E. Matthews, Editorial Vice-President, on behalf of S. P. Solow, Chairman of the Journal Award Committee:

The Journal Award was established in 1933 and was first awarded in 1934 to the late Dr. Peter A. Snell for his paper on an experimental study of visual fatigue that appeared in the Society's *Journal* in May 1933. It is of interest to note that this work was done under the only fellowship ever granted under the auspices of our Society. The Award this year marks the 25th time that it has been given.

The basic qualifications under which the Journal Award is made are as follows:

(1) The paper must deal with some technical phase of motion-picture and/or television engineering.

(2) No paper given in connection with the receipt of any other Award of the Society shall be eligible.

(3) In judging the merits of the paper, three qualities shall be considered (a) technical merit and importance of material, 45%; (b) originality and breadth of interest, 35%; (c) excellence of presentation, 20%.

It is now my privilege to announce to you that the Journal Award Committee has recommended that the Award for 1958 be made to Mr. George Lewin of the Army

Pictorial Center in Long Island City, New York, for his papers in the September and December 1957 issues of the *Journal* on the infrared transparency of magnetic tracks.

The author describes his discovery that magnetic tracks are substantially transparent to infrared light. Utilizing the infrared sensitivity of the lead-sulfide photoconductive cell, he shows that excellent reproduction of an optical track can be achieved even though it is completely covered by a magnetic stripe. In this way, a print can be made carrying two excellent soundtracks presenting the possibility of bilingual or stereophonic recordings.

The Committee has voted the Journal Award to Mr. Lewin not only for the caliber of his discovery, but also for the thoroughness and clarity with which he has presented his data on the effects of stripe thickness, aging, exciter lamps, and photocells on frequency responses and sound levels. It is interesting to point out that at the conclusion of the presentation of the first paper by Mr. Lewin at the Convention of the Society in Washington, on May 3, 1957, the entire audience rose and warmly applauded the speaker.

Geoge Lewin was born in New York City and was graduated from Cooper Union Institute of Technology. He then took a brief excursion away from engineering which may well have increased his appreciation of good sound by being a professional musician—pianist — in vaudeville, on shipboard and in summer resorts. Then he came back to engineering with the advent of sound in motion pictures at Paramount's Long Island Studios in 1928, with such stars as Eddie Cantor, Claudette Colbert and Ginger Rogers.

For the next twelve years he made the rounds of the studios in New York and Hollywood, and then returned to the very studios in which he started, but this time taken over for the new Army Pictorial Service in 1944 for World War II. There he has been ever since in his present position as Chief of the Pictorial Engineering Office. He has given special study to the important Army work of language dubbing for films and the practical Reversing System for Narration.

Mr. Lewin has been a regular contributor to the *Journal* and allied magazines, starting with an article on "Dubbing" in January 1931. His work for the Society includes service on the following committees: Papers, 1951–54, and 1956; Journal Award, 1955–56; Warner Award, 1957–58. He was one of the Atlantic Coast Managers in 1954–55 and a Governor of the Society in 1955–56. He has always been an active participant in Section meetings and with his wife, Sylvia, has been most faithful at the Conventions. He was made a Fellow of the Society at the 1956 Convention. He is also a member of the Audio Engineering Society.

In accepting the Award, Mr. Lewin expressed deep appreciation for the assistance given him in preparing the presentation that earned the award and said that he was accepting the honor "on behalf of all these people." Following is the complete text of his acceptance:

In accepting this great honor I must give the credit to the many people who helped me so generously in preparing not only the two papers which earned this award but also the demonstrations which were an integral part of them. I wish to mention particularly Ellis W. D'Arcy, to whom I first demonstrated the discovery and who urged me to write the first paper; Edward Schmidt of Reeves Soundcraft, who provided me with the spectrograms which explained the transparency effect; W. W. Wetzel of Minnesota Mining, T. C. Bagg of the National Bureau of Standards, and Malcolm Townsley of Bell & Howell, who collaborated in preparing the illustrations which made my presentation so much more effective; Joseph E. Aiken and Jack Greenfield of the Naval Photo Center who, in a true spirit of interservice cooperation, loaned me the Navy's projection equipment for putting on my first demonstration; Col. R. H. Ranger of Rangertone, who foresaw the possibilities of the discovery for making stereophonic recordings on 16mm film and prepared the stereophonic demonstration film which accompanied my second paper; and Max Kosarin of the Army Pictorial Center, who provided the film material from which I was able to prepare the dual language demonstration film which accompanied my second paper. I must also give credit to Gar Misener of Capital Film Laboratories in Washington, and Everett Hall of The Thomas Watson Company in New York, who provided me with Minnesota Mining Laminated stripe demonstration material; Ernest Frank of Reeves Soundcraft, who assisted me in preparing data on Reeves Stripe material, and Emil Vorosek of Reeves Studios, who helped me in obtaining the intermodulation data on 35mm striped film for my second paper.

General O'Connell, Chief Signal Officer

of the U.S. Army, by his generous personal commendation to me after the publication of the first paper, provided the incentive to continue the work which led to the second paper.

Herbert T. Kalmus Gold Medal

Merle L. Dundon was awarded the Herbert T. Kalmus Gold Medal for contributions to the design and development of color products. The Citation, prepared by the Herbert T. Kalmus Gold Medal Award Committee, was read by the Chairman, Herman H. Duerr:

The Herbert T. Kalmus Gold Medal Award was established by the Society in 1955. It is awarded each year to an individual who has made an outstanding contribution to the development of color films, processes, techniques or equipment useful for color motion pictures for the theater, television or other commercial uses. Previous recipients of the Kalmus Gold Medal are Wesley T. Hanson in 1956 and Wadsworth E. Pohl in 1957.

I have the honor and the pleasure tonight, as Chairman of the Kalmus Gold Medal Award Committee, to announce the selection for 1958. The recipient of the Herbert T. Kalmus Gold Medal for this year is Dr. Merle L. Dundon.

Dr. Dundon is presented this award for his many contributions to the design and development of color products such as Kodachrome-type color films, Eastman Color Negative and Color Print Film. In particular, the Award is in recognition for this valuable contribution to the development and improvement of the Eastman Color Intermediate Film, which has become an important link in the production of color duplicate negatives.

Dr. Dundon was graduated from Mt. Union College in 1917 with the Degree of Bachelor of Science. During World War I he was stationed at the American University Experiment Station of the Chemical Warfare Service. After the war he attended Ohio State University and received the Degree of Master of Science in 1920 and the Degree of Doctor of Philosophy in 1922.

In 1923, Dr. Dundon joined the Research Laboratories of the Eastman Kodak Company, specializing in photographic chemistry and processing. In 1929 he was transferred to the Film Emulsion Department, where he is presently in the position of Assistant Manager of the Film Emulsion and Plate Manufacturing Division.

The Bronze Medal of the Société Française de Photographie was awarded to Dr. Dundon in 1924. Mt. Union College honored him with a Doctor of Science degree in 1943. He is an honorary member of several scientific societies and a Fellow of the Photographic Society of America.

To this distinguished list of accomplishments, the Society of Motion Picture and Television Engineers is proud to add the 1958 Herbert T. Kalmus Gold Medal Award.

In accepting the Award Dr. Dundon pointed out that among the many workers on color film and processes at Kodak Park in Rochester there has always been a fine spirit of cooperation and team work. Although he appreciated very greatly the honor of receiving this Award, he stated that it really represented a recognition of the work of many individuals working together as a team.

David Sarnoff Gold Medal Award

Albert Rose was awarded the David Sarnoff Gold Medal for contributions to the development of orthicon, image-orthicon and vidicon television pickup tubes. The following citation, prepared by the David Sarnoff Award Committee under the chairmanship of William B. Lodge, was read by Axel G. Jensen, Engineering Vice-President.

Albert Rose was born in New York City on March 30, 1910. He received the Degree of Bachelor of Arts from Cornell University in 1931 and the Degree of Doctor of Philosophy in Physics in 1935. From 1931 to 1934 he was a teaching assistant at Cornell University. He joined RCA in 1935 and since then has been a member of the research staff, first in Harrison and since the opening of the Princeton Laboratories in 1942, at Princeton, N.J.

Dr. Rose is well known for his work on television pickup tubes. In the early development of electronic television the Iconoscope was the most widely used pickup tube but it had a number of defects which made operation difficult and critical. Many of these defects were due to the use of a high velocity scanning beam. Analyzing the problem, Dr. Rose stimulated and participated in research toward a low-velocity

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CHICAGO, Zenith Cinema Service, Inc.; **LOS ANGELES,** Birns & Sawyer Cine Equipment; **NEW YORK** Camera Equipment Co.; **SAN FRANCISCO,** Brooks Camera Co.; **BELGIUM,** Brussels, S.O.B.A.C., S.A. (Societe Belge D'Applications Cinematographiques); **CANADA,** Toronto, Ontario, Alex L. Clark, Ltd.,; **DENMARK,** Copenhagen, Kinovox Electric Corp.; **ENGLAND,** London, W-1, DeLane Lea Processes, Ltd.; **HONGKONG,** Supreme Trading Co.; **INDIA,** Bombay, Kine Engineers; **ITALY,** Rome, Reporfilm S.R.L.; **JAPAN,** Tokyo, J. Osawa & Co., Ltd.; **MEXICO CITY,** D.F., Henri A. Lube; **PAKISTAN,** Karachi 3, Film Factors Ltd.; **SWITZERLAND,** Zurich 7/53, Rene Boeniger; **THAILAND,** Bangkok, G. Simon Radio Co., Ltd.

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beam tube to overcome many of the existing problems. This work culminated in the Orthicon tube a description of which was published in 1939.

Pursuing this line during and following World War II, Dr. Rose led a research group in the development of the Image Orthicon which incorporated major advances resulting from studies in which he had been engaged during the preceding decade. Introduced in 1946, the Image Orthicon provided television for the first time with the answer to its need for a camera that might "see wherever the human eye could see." Since its introduction the Image Orthicon has been the eye of the television broadcast industry.

Subsequent study by Dr. Rose in the area of photoconductivity provided the basic contribution to the development of the Vidicon tube by the research group under his direction. The Vidicon has made possible a simple and economical link between the motion-picture and television arts, permitting the direct pickup and transmission of filmed program material.

Although others have contributed important features to the Orthicon, Image Orthicon, and Vidicon, Dr. Rose's continuing vision, scientific guidance, and stimulating leadership have been essential in the successful conclusion of all three projects.

Samuel L. Warner Memorial Award

The following citation, which had been prepared by the Samuel L. Warner Memorial Award Committee under the chairmanship of Gordon F. Sawyer, was read by Axel G. Jensen, Engineering Vice-President:

It is my privilege to announce that George Lewin, Chief of Pictorial Engineering for the Army Pictorial Service and a Fellow of our Society, is to be this year's recipient.

The Samuel L. Warner Memorial Award is given to the individual who, in the opinion of a special committee, was responsible for an invention or method likely to have the most beneficial effect on the recording and reproduction of sound and picture.

In their search for a worthy recipient the committee members are charged with the responsibility of reviewing inventions and methods concerned with sound recording and reproduction for the previous five years.

George Lewin entered the sound recording field in 1928 and has been constantly working for its betterment ever since. It was the unanimous opinion of our committee that Mr. Lewin's discovery and research on the phenomenon of transparency of magnetic coatings to infrared light sources and its application to dual sound reproduction from either the magnetic track or the underlying optical track was an invention of significance and method with great potential application.

In addition to this invention, George Lewin has made many practical contributions, both in equipment design and techniques employed in "dubbing."

In accepting the Award, Mr. Lewin said:

I welcome this opportunity to express my appreciation to the many people at the Army Pictorial Center who gave me the opportunity and helped me in the work

which has been recognized by this Award. I would like especially to mention three people who have since passed away: William Raycroft who did some of the circuit design involved in much of our original conversion from photographic to magnetic recording; Steve Szeglin who did much of the mechanical design involved in our "reversible" system for narration recording and the "magnetic loop" system of lip-synchronizing; and John W. Butler who, as Chief of our Studio Division at that time, encouraged the work we were doing.

Among the living, I wish to extend full credit to James Kennedy who supervised all of the work, contributed ideas of his own and was mainly responsible for putting into actual practice many of the ideas which may have originated with me but could very well have remained merely as ideas had it not been for Mr. Kennedy's energetic and conscientious efforts bringing them to successful culmination. I also greatly appreciate the efforts of Colonel Al Dillinger as former Chief of Sound Branch and later Chief of Studio Division, and Ed Dreyer as present Chief of Recording Section, in energetically encouraging the application of the new methods to actual production use in the face of the natural reluctance of many old-timers to adopt new methods. And above all, I appreciate the encouragement of this Society's Executive Secretary, Colonel Stodter, who was Commanding Officer of the Army Pictorial Center and later Chief of Army Pictorial Service Division, and Colonel Lindsay and Colonel McCrary who succeeded him during the period when these various projects were being developed.

With regard to my work in the use of ¼ in. synchronous tape, I must point out that the real pioneering work was done by Col. R. H. Ranger of Rangertone and W. D. Fling, who was at that time Chief Engineer of Fairchild Recording Company. I am proud to have had an opportunity to participate in some of the early tests of their systems and to have been instrumental in encouraging some of the first applications of their equipment to certain of our activities at the Army Pictorial Center.

Education, Industry News

John B. Olsson has been appointed Assistant Sales Manager for Beattie-Coleman Inc., 1000 N. Olive, Anaheim, Calif. For the past seven years he has been with Houston Fearless Corp. where he has served as Sales Engineer, Advertising Manager, and Laboratory Contact Representative for the firm's color film laboratories in Burbank, Calif. He has also acted as chief civilian contracting officer for photographic equipment purchased for the Army, Navy and Air Force at Wright Patterson AFB. He has also been Chairman of the SMPTE Exhibit Committee for the past two Los Angeles Conventions.

K. D. Shamberg, film and TV engineer, is now engaged as an independent producer, associated with City Film Center, 66-40 69th St., Middle Village, L.I., N.Y. City Film Center is working on new formats for television, attempting a "different" type of entertainment.

employment service

These notices are published for the service of the membership and the field. They are inserted three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Motion-Picture Engineer. Available for new position February 20, 1959; will consider job in any part of the world. Now completing contract with Reevesound Co., New York, installing laboratory overseas. Formerly with Capital Film Labs, Washington, D.C., for several years. Have designed and built lab equipment for a number of years for the trade (firm name in Washington, D.C., is Telex Films). Have the experience to do capable work in production, editing, sound or lab. Complete résumé upon request. Would prefer any new overseas assignment to start by March 10, 1959. Write airmail: Victor E. Patterson (USOM), American Embassy, APO 271, New York, N. Y.

Television Engineer. French citizen, 7 yrs experience TV research in Paris, subsequently engineering manager of TV station in Casablanca, Morocco, seeks position in United States or Mexico, preferably with an American company. Degrees in electrical and radio engineering. Age 34, married. Write: Lucien Chareyre, 37 rue de Mareuil, Casablanca, Morocco.

Cameraman-Editor experienced in all phases of film production, feature films, commercials, TV documentaries, sound recording and laboratory. Desire permanent position with production company or television station. Will work in studio and/or anywhere on location. Knowledge of French, Italian and Arabic. Write to A. P. Mamo, 7945 Cartier Street, Montreal, Quebec, Canada.

Motion-Picture Production. Experienced in film production, studio and location, educational, industrial and TV films. 15 years in industrial films, 6 years producing TV commercials. Seeking a position as production executive with a commercial or industrial motion-picture unit. Experienced in various phases of film production; operated most 35mm and 16mm cameras, directed industrial films, produced TV commercials. Excellent references. Résumé on request. Write: Edw. A. "Jack" Price, 2417 Crest Ave., South Bend 14, Indiana.

Educator - Cameraman - Producer. Available every summer for either industry or education. Experienced in educational films, TV commercials, public relations films, newsreel work and live educational television. Degrees: B.S. in Ed., M.A. Interested either in production or organization, setting up program and teaching others to carry on. Also interested in any type of employment in motion-picture industry for which qualified. Experienced in every technical phase of motion-picture production. Own complete production equipment, cameras, sound, lights, etc. Age 42. Teacher in winter. Available from June 12 to Labor Day. Salary open. Henry E. Eisenkramer, 7550 Washington Ave., University City 5, Mo. VOlunteer 3-5669.

Chemistry and Chemical Physics. Director of Research and Experimental Engineering for 20 yrs, predecessor of Harris Intertype Corp.; over 70 patents and applications in photographic and photomechanical fields; member many scientific organizations. Special interests: light sensitive substances, developers, phototypesetting, highspeed data recording, photopolymerization. Overseas contacts in research and development. Available full time or on a consulting basis. Would relocate. William H. Wood, Route 1, Box O, Rockbridge, Ohio.

Motion-Picture Writer, Director or Unit Manager with some TV experience returning from 8 yrs work in Middle East. B.A., M.A. in Cinema from USC. Wants position with vigorous film or television company. Have family, will relocate. Résumé on request. Write: John H. Humphrey, Apt. 604 West, 74-10 35th Ave., Jackson Heights, N. Y.

Photographic Administrative and Technical Specialist. 21 yrs experience in laboratory administration, sales administration, selling, quality control, personnel supervision, camera work and production. Heavy experience in color with leading laboratory. Seeking connection in administrative capacity with major TV or film company. Detailed resume on request. Willing to relocate. Robin R. Lewis, 4 Arbor Rd., Syosset, N. Y. WAlnut 1-0063.

Audio-Visual Production. Freelance experienced in all phases of audio-visual production wants assignments on West Coast. Fully equipped for 35mm slidefilms, slides and 16mm motion-picture production; also equipped for editing. References available. Write: J. S. Paul, c/o J-Me Films, P.O. Box 6143, Bakersfield, Calif.

Producer-Writer. Motion-picture and educational TV experience. B.S. Quantitative Biology, MIT, 1957; B.S. Motion Pictures, Boston Univ., 1955. Age 25. Single, locate anywhere. Complete resume on request. Write: Marc E. Finkel, 44 Kimball Rd., Chelsea 50, Mass.

Theatre Sound and Projection Technician, 37, married, seeks position with Canadian theatre supply company. Experienced in installation of theatre projectors and some theatre sound and p.a. systems, maintenance of Simplex and other projectors, sound work on Ballantyne and other sound systems; first class B.C. projectionist since 1949 (in projection 13 yrs); qualified TV service technician, have built own test equipment including VTVM, signal generator, oscilloscope, complete television receiver and miscellaneous electronic test equipment. Employed as projectionist by Famous Players Canadian Corp. since 1950; seeks position that will further utilize qualifications; willing to relocate anywhere in Canada. Write: A. P. Mulcahy, 604 Nicola St., Kamloops, B.C., Canada.

Industrial Photographer, cameraman, producer. Broad experience: still and motion pictures production; camera, editing, darkroom b&w and color printing and processing, transparency duplication. 18 yrs working practice in industrial, commercial, educational, scientific, medical and documentary films. Good knowledge of production and use of audio-visual media. Presently working as production supervisor for a large color lab, but finishing agreement and available on short notice. Good background, master's degree; ambitious and reliable personally, Spanish language; able to manage production unit, design and organize a photo dept. Have some equipment, will relocate. Write M.G., 68-46 Groton St., Forest Hills 75, N.Y.

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FOR SALE: Maurer 16mm optical recorder, Model D, Serial RD166, complete with recording head, amplifier, power supply, line transformer and carrying cases. Unit in beautiful condition—sound reproduction is of finest quality. A real bargain $2,500.00. Pan-American Films, 735 Poydras St., New Orleans, La.

Motion-Picture Production, Presentation. Energetic, versatile, age 26. Thoroughly experienced in all technical phases of motion-picture production, 16 & 35mm, including formulation, writing and editing of scripts for TV commercials, educational, industrial, R&D and public relations films. Work experience includes: Prod. Asst., Elliot-Unger-Elliot Motion Pictures and TV Commercials; Coordinator, Audio-Visual Dept., Univ. of Miami; just completed 2 yrs military service, U.S. Army Ord. as motion-picture director, technical writer and cinematographer. Productions distributed internationally. "SECRET" clearance, U.S. Army Ord. Eduction: BBA degree, supplemented by courses in electronics, education, technical writing, journalism and composition. Willing to relocate. Resume on request. Available for personal interview with films and scripts. Larry Ross, 55 Payson Ave., New York 34. Williams 2-0560.

Positions Available

Cameramen. Staff position. References and resume of experience required. Confidential. **Sound Technicians.** Experience, references. Permanent position. **Laboratory Technicians.** Timing experience. Permanent position. Write: I. C., 423 East 90 St., New York 28.

Television Engineers. Positions available for television engineers meeting the following minimum requirements: (a) BS degree with a minimum of 1 yr of TV equipment design on camera equipment, broadcast or industrial systems; or (b) 4 yrs experience on television design work in lieu of BS degree with 1 yr spent on television camera design. Young and expanding company located in smog-free Orange County, close to beaches and downtown Los Angeles. Excellent living conditions. Salary dependent upon experience and education. Send complete resume to Personnel Dept., Interstate Electronics Corp., 707 E. Vermont Ave., Anaheim, Calif.

8mm Movie Design Engineer, Production Engineer, Development Engineer. These are specific openings in our 8 mm movie program. Applicants must be graduate engineers with experience in engineering and manufacturing amateur motion-picture equipment. These openings are the result of a strong new products program at Argus Cameras and offer a rare opportunity to use your past experience in the motion-picture field with a growing and progressive company. Send resume to Employment Manager, Argus Cameras, Ann Arbor, Mich., stating age, education, work history and salary requirements.

Laboratory Control. Philadelphia motion-picture laboratory wants young man. Will have complete responsibility for mixing and sensitometric control of B&W processing chemicals and mechanical maintenance of Bell & Howell printers including balancing of exposure lights. Chemical and mechanical background plus knowledge of motion-picture laboratory techniques required. Send reply to Louis W. Kellman, 1729 Sansom St., Philadelphia 3, Pa.

INDEX TO SUBJECTS — January – December 1958 • Volume 67

ACOUSTICS

Microphone, electrostatic, uniangular, *Olson* and *Preston*, Nov. pp. 750–754

APPARATUS

Color-film analyzer, instantaneous electronic, *Loughlin, Page, Bailey, Hirsch, Miller* and *Giarraputo*, Jan. pp. 17–26
Color timer for motion-picture films, a new, *Stafford* and *Baumbach*, Feb. pp. 81–83
Color timing calculating machine, *Keene, Sant* and *Clifford*, Nov. pp. 763–767
Color timing method and calculator for subtractive motion-picture printers, *Keene*, June pp. 404–408
Embossed kinescope recording film, devices for making sensitometric exposures on, *Crane* and *Evans*, Jan. pp. 13–16
Exhaust hood, dirt-free, for cleaning film, *Ott*, Oct. pp. 689–690
Film-cleaning drum, powered, *Brueggemann*, Oct. pp. 686–688
Film editing, television, automatic (Inspect-O-Film), *Grunewald* and *Wallace*, June pp. 397–400
Lip-synchronized sound recording, 16mm magnetic-optical sound projector used, *Askren* and *Dwyer*, Jan. pp. 32–34
Picture quality control, color television, stabilized monitor for, *Gloystein* and *Kellaway*, Mar. pp. 157–162
Silver-recovery apparatus for operation at high current densities, *Cedrone*, Mar. pp. 172–174
Subtractive motion-picture printers, color timing method and calculator for, *Keene*, June pp. 404–408
Television viewfinder, improved, for motion-picture production, *Freund*, Nov. pp. 745–746

APPLICATIONS

Collision injury research, photographic instrumentation for, *Severy*, Feb. pp. 69–77
Operation Deepfreeze, ruggedizing cameras for, *Conger*, Jan. pp. 35–37
Projector, Siemens dual-strip 16/16, with synchronous motor (Abridgment), *Kronenberger*, July p. 486
Thin cathode-ray tube, development of, *Aiken*, July pp. 452–455
Transparent cathode-ray screens, development and applications, *Feldman*, July pp. 455–460

ARCS, Projection

Blown arc for projection, improvements in, *Ayling* and *Hatch*, Oct. pp. 693–695
Xenon-arc projection lamp, *Reese*, June pp. 392–396
Xenon high-pressure lamps in motion-picture theaters, *Ullfers* (Abridged by *Hurd*), June pp. 389–392

AUTOMATIC DEVICES

Announcing techniques, automatic, for television stations, *Isberg*, Feb. pp. 87–91
Cuing, automatic, of television film projectors, *Melchionni*, Feb. pp. 92–94
Exposure control, automatic, for high-resolution camera, *Economou, Luban* and *Mehr*, Apr. pp. 249–251
Film editing, television, automatic (Inspect-O-Film), *Grunewald* and *Wallace*, June pp. 397–400
Printer Light Selector, automatic for Bell & Howell D and J Printers, *Wargo, Little* and *Baumbach*, Feb. pp. 78–80

AWARDS and HONORS (See SOCIETY ACTIVITIES)

BIOGRAPHICAL NOTES

Davis, Raymond, *Smith*, Nov. p. 786
Geib, Ervin R., retires, July p. 500
Mertz, Pierre, retires, May p. 344
Tykociner, Joseph T., *McCullough* and *Aiken*, Aug. pp. 521–523

BOOK REVIEWS

Animals in Motion, Eadweard Muybridge, Nov. p. 792
Automatic Record Changer Manual, Howard W. Sams Co., (a notice) Mar. p. 208
Bibliography on Color, Inter-Society Color Council, (a notice) Oct. p. 714
Care and Conservation of Motion-Picture Film, W. D. Korowkin, Oct. p. 705
Closed-Circuit Television Systems, Radio Corp. of America, (a notice) Oct. p. 712
Closed Circuit TV System Planning, M. A. Mayers and R. D. Chipp, Jan. p. 41
Dictionary of Photography and Motion-Picture Engineering Vol I: English-German-French, W. Grau, Nov. p. 790
Eastman Motion Picture Films for Professional Use, (a notice) Oct. p. 712
8mm Cine Manual, H. A. V. Bulleid, Jan. p. 42
Elements of Magnetic Tape Recording, N. M. Haynes, Oct. p. 710
Engineering Economy (3d ed.), C. E. Bullinger, Oct. p. 704
Film en Televisie Gids Voor Nederland, Stichting Instituut Voor Filmdocumentatie, Amsterdam, (a notice) Oct. p. 712
Graphic Communication and the Crisis in Education, Audio Visual Communication Review, Vol. 5., No. 3., N. E. Miller, (a notice) Jan. p. 46
Handbook of Noise Control, ed. C. M. Harris, Aug. p. 550
International Lighting Vocabulary, International Commission on Illumination, (a notice) Oct. p. 710
International Screen Production Handbook, ed. C. W. Curran, Nov. p. 794
Introduction to the Theory of Random Signals and Noise, W. B. Davenport, Jr., and W. L. Root, Nov. p. 791
Kodak Pamphlet D-21, (a notice) Oct. p. 712
The Liveliest Art, A. Knight, Jan. p. 44
Magnetic Sound Recording for 16mm Motion Pictures, Eastman Kodak Co., (a notice) Oct. p. 712
The Measurement of Colour, W. D. Wright, June p. 420
Microphotography, G. W. W. Stevens, Oct. p. 710
Modern Geometrical Optics, M. Herzberger, (a notice) Oct. p. 712
The Movies, R. Griffith and A. Mayer, Jan. p. 42
Photography in Your Future, A. L. TerLouw, (a notice) Apr. p. 275
Photo-Lab Index, Quarterly supplement No. 74, (a notice) Jan. p. 46
Photojournalism, A. Rothstein, (a notice) Jan. p. 44
Posing Patterns, L. E. Broome, Nov. p. 792
Proceedings of the National Electronic Conference, Vol. 13, Aug. p. 552
Psychological Effects of the "Western" Film: A Study in Television Viewing, F. E. Emery and D. Martin, Nov. p. 794
The Reproduction of Colour, R. W. G. Hunt, Nov. p. 792
Selected References on Audio-Visual Publications, Eastman Kodak Co., (a notice) Oct. p. 712
Tape Recorder Manual, Vol. I, Howard W. Sams & Co., (a notice) Mar. p. 208
The Technique of Film Music, R. Manvell and J. Huntley, Sept. p. 638
Technique of Film and Television Make-up, V. J-R Kehoe, Oct. p. 704
Techniques of Magnetic Recording, J. Tall, Apr. p. 274
Technique of Stage Lighting, R. G. Williams, Oct. p. 708
Television Factbook 27th ed., Television Digest, (a notice) Oct. p. 712
Television Production—The TV Handbook & Dictionary, H. W. McMahan, June, p. 420
Television in Science and Industry, V. K. Zworykin, E. G. Ramberg and L. E. Flory, Sept. p. 639
Test Equipment Manual, Howard W. Sams Co., (a notice) Apr. p. 274
The Transistor, 1948–1958, June 1958 Bell Laboratories Record, (a notice) Nov. p. 791
TV Distribution Systems and Antenna Techniques, J. Beever, Oct., p. 708
Underwater Photography (enlarged 2d ed.), H. Schenck, Jr., and H. Kendall, Mar. p. 208
Underwater Photography Simplified, 2d ed., J. Greenberg, Apr. p. 274

CAMERAS (see also HIGH-SPEED PHOTOGRAPHY, and TELEVISION)

Iris control, direct-drive, automatic, *La Rue, Bagby, Bushman, Freeland* and *MacMillan*, Sept. pp. 600–604
Operation Deepfreeze, ruggedizing cameras for, *Conger*, Jan. pp 35–37

COLOR

The Adventure of Technicolor, *Kalmus*, Dec. pp. 829–830
Color-television images and perception of color detail, on the quality of, *Schade*, Dec. pp. 801–819

CURRENT LITERATURE

Feb. p. 112; Apr. p. 275; Oct. p. 714; Nov. p. 794

EDITING

Editing video-tape recordings, electronic marking and control for rapid location of vertical blanking area, *Roizen*, Nov. pp. 732–733
Film editing, television, automatic (Inspect-O-Film), *Grunewald* and *Wallace*, June pp. 397–400
Splicing video tape, factors affecting, *Machein*, Nov. pp. 730–731

EDUCATION

Education—A New Era Begins, *Mitchell*, Dec. pp. 828–829

EDUCATION, INDUSTRY NEWS (a column of brief items)

In Jan., p. 40
The Eighth National Conference on Standards
Three members of Society made Fellows of IRE
Alan Cook, Ansco post
William H. Metzger, Ansco post
Daniel and Florence Guggenheim Fellowships
Rediffusion Ltd.
International Experimental Film Competition
Education—New Era, Mitchell

In Feb., pp. 110–111
British Broadcasting Corp. television center
Massachusetts Veterinary Assn., a series of closed-circuit TV programs
The Eighth Annual International Symposia of the Microwave Research Institute
An experiment in community education
Plans for a new $10 million United Engineering Center
Bulletins on Television in Teacher Education
American Institute of Physics, an educational program
The 10th Annual Conference on Electrical Techniques in Medicine and Biology

In Mar., pp. 200–204
Academy Awards
Pay TV
The Kodak Building at the Brussels Universal and International Exhibition
Educational television
Armour Research Foundation, 734 research programs
Preservation of sound recordings
20th Century-Fox, land-development plan
Norwood L. Simmons and Vaughn C. Shaner at Eastman Kodak Co.
Robert W. Eberenz, Byron Inc. post
Boyce Nemec, Reevesound Co. post
Howard A. Mann, Roger Wade Productions Inc. post
Thomas B. Williams, Roger Wade Productions Inc. post
A. A. Ward at Altec Companies Inc.
John K. Hilliard at Altec Lansing Corp.
A. M. Zorem speaker at Electronic Components Conference
Walter C. Granville, President of Inter-Society Color Council
Lee E. Jones, Executive Vice-President of Neumade Products Corp.
Myron Baldwin at Instrument Div. of Beckman & Whitley Inc.

In Apr., p. 270
Photokina 1958
Charles Ginsburg, Vladimir K. Zworykin television prize
The People-to-People Program launched by President
Subliminal perception

In May, pp. 346–348
University of California, Los Angeles, two courses in motion pictures and three in television-radio
Fourth Annual Robert Flaherty Seminar
Brigham Young University, new motion picture studio
Micro-Photography Co.
Bob Jones University film at International Film Festival

In June, pp. 416–418
Telemovies in Bartlesville, Okla.
Subcommittee on Television and Teacher Education of American Assn. of Colleges for Teacher Education
Motion-Picture Industry Credit Group
Purdue University, conference on televised instruction
Society for the History of Technology
English translations of Russian scientific and technical journals
National Audio-Visual Assn. Convention
LaVezzi Machine Works
Mole-Richardson, a display room
John Mercer, Southern Illinois University post
Lewis L. Mellor, Wollensak Optical Co. post
Walter Clark named chairman of Honors Committee of SPSE
Victor M. Salter, Du Pont post
Harold W. Lindsay Fellow of Audio Engineering Society

In July, pp. 494–498
Society of Photographic Scientists and Engineers Convention
Bernstein report on motion-picture industry
Institute of Film Techniques, City College, New York
Unesco, Department of Mass Communication
Le Merle (*The Blackbird*) prizewinner World Film Festival Brussels
Cotton: Nature's Wonder Fiber entered at Venice Film Festival
Fastex Photography, an Engineering Tool

In August, p. 542
American Society for Engineering Education, survey of technical institutes
Argonne National Laboratory, eight scientific motion pictures produced
Creative Film Foundation, awards
John I. Crabtree and Wesley T. Hanson, honorary degree of Master of Photography
32d National Colloid Symposium
Robert W. Wagner, head of Cinema Dept., Univ. of Southern Calif.
George L. Oakley, Bell & Howell post

In Sept., pp. 628–634
Iowa State College, recording-reproducing color television system
The Flying Angel, Unusual Films of Bob Jones University
Film Festival and Audio-Visual Exhibit, William Samuel Johnson School
American Film Festival, Statler Hotel
CBS Laboratories Research Center
Canadian Kodak Co. Ltd., construction.
Howard W. Hoadley, Editor of News Bulletin of SPSE
Arthur H. Bolt, Triad Corp. post
Adrian Woolery, contributing writer for The Technique of Film Animation
Murder on the Screen, a film
Walter Reed Army Medical Center, closed-circuit TV installation
University of Miami, report on Broadcasting and Film Activities
"Darkroom Design and Construction" and "16mm Kodak Movie Films — Data and Selection"

In Oct., pp. 696–698
Course in Magnetic Video-Tape Recording of Television
Artiscope animation process
Axel G. Jensen made Knight of Order of Dannebrog
Portable auditorium
Twelve best films
Tenth International Cinematography Engineering Congress
Film courses, Northwestern Univ.
National Camera Repair School accredited
Francis G. Semere, at Thompson-Ramo-Wooldridge
Vin Agar, Western Div. Manager, Natural Lighting Corp.
Television service within U.S. Information Agency
"It smells"
Twenty-fifth anniversary of founding of Reeves Sound Studios
Marvin Schulman, post at TV Station KCOP
Series of 16mm color films called Navy Research and Development Film Reports

In Nov., pp. 778–784
Western Electronic Show exhibits
Dr. James R. Killian addressed Annual Meeting of Land Grant Colleges
Worlds of theater and classroom
14th Annual National Electronics Conference, a report
SPSE honors Louis-Philippe Clerc, Cyril J. Stand, Edward K. Kaprelian
International Convention on Transistors and Associated Semiconductor Devices
Alfred N. Goldsmith, to Board of Directors, RCA Communications Inc.
Solita Palmer, to write music for film *Statehood*
Louis L. Behrmann, Unicorn Engineering Corp. post
CBS Laboratories opened Research Center

In Dec., p. 847
John B. Olsson, Beattie-Coleman post
K. D. Shamberg, City Film Center post

ERRATA
Color Timing Method and Calculator for Subtractive Motion-Picture Printers, *Keene* (June pp. 404–408), Nov. p. 768
Directory for Members (Apr. 1958, Pt. II, pp. 9, 30, 36, 44 and 48), July p. 479
Discussion on Video-Tape Recording, Washington Convention—*Nov. p. 737*, footnote, *read* April 29, 1957 *for* April 29, 1958.
NARCOM Plan for Transatlantic Television and Other Wideband Telecommunication Services, *Halstead* (Mar. pp. 134–138), Apr. p. 256
Practical Film Cleaning for Safety and Effectiveness, *Fassett*, *Kolb*, and *Weigel* (Sept. pp. 572–589), Nov. p. 768
Progress Report (May 1958, pp. 289, 306 and 322), July p. 479

FILM

General
American Standard, Dimensions for 16mm Motion-Picture Film, 2R-2994, PH22.110-1958, Aug. p. 539
American Standard (Revision of PH22.73-1951) Dimensions for 35mm Motion-Picture Film, Perforated 32mm, 2R-2994, PH22.73-1958, June p. 410
American Standard, Dimensions for 16mm Motion-Picture Film, 1R-2994, PH22.109-1958, Aug. p. 538
American Standard, Four Magnetic Sound Records on 35mm Film, PH22.108-1958, June p. 411
American Standard, Proposed, (Revision of Z22.31-1946) Motion Picture Safety Film, PH22.31, Feb. p. 103
American Standard (Revision of PH22.87-1953) 100-Mil Magnetic Coating on 16mm Film, Perforated One Edge, PH22.87-1958, June p. 409
American Standard, Scene-Change Cueing for Printing 16mm Motion-Picture Film, PH-22.89-1958, June p. 411
16mm professional film—a proposal (Letter to the Editor), *Lumley*, July p. 487

Cleaning
Cleaning motion-picture film, a machine for, *Turner*, *Scudder* and *Deane*, July pp. 480–485
Exhaust hood, dirt-free, for cleaning film, *Ott*, Oct. pp. 689–690
Film cleaning drum, powered, *Brueggemann*, Oct. pp. 686–688
Film cleaning, practical methods, for safety and effectiveness, *Fassett*, *Kolb*, and *Weigel*, Sept. pp. 572–589

Color
Color-film analyzer, instantaneous electronic, *Loughlin*, *Page*, *Bailey*, *Hirsch*, *Miller* and *Giarraputo*, Jan. pp. 17–26
Dye stability, Eastman Color Print Film, *Horowitz* and *Weller*, June pp. 401–404
Lenticular color-film process, optics of, *Kingslake*, Jan. pp. 8–13
16mm Super Anscochrome films, *Forrest*, Oct. pp. 691–693

Test
American Standard, Proposed, 16mm Azimuth Test Film, Magnetic Type, PH22.114, Apr. p. 263
American Standard, Proposed, 16mm Flutter Test Film, Magnetic Type, PH22.113, Feb. p. 103

Wear
Motion-picture release prints, prolonging the life of, *Johnson*, Sept. pp. 590–592
Static markings on motion-picture film, causes and prevention of, *Kisner*, Aug. pp. 513–517

GENERAL
Education—a new era begins, *Mitchell*, Dec. pp. 828–829
Human engineering problems in television control room design, *Pores*, Oct. pp. 672–675
Parade control and field exercises, television for, *Dakin*, *Martin*, *Bue* and *Smith*, July pp. 461–463
Research and development, Army television (special requirements for military equipment), *Huber* and *Le Vino*, July pp. 465–469
A Writer-Producer Looks at SMPTE, *Brackett*, June pp. 414–415

HIGH-SPEED PHOTOGRAPHY

General
Fourth High-Speed Congress, program received, Aug. p. 540
Fourth International High-Speed Photography Congress, June p. 416
High-speed photography activities (report), Apr. p. 264
Lenticular-plate cinemicrograph and image dissection process, an analytical evaluation of, *Huggins*, Aug. pp. 523–526

Applications and Equipment

Collision injury research, photographic instrumentation for, *Severy*, Feb. pp. 69–77
Flying camera stations, *Kinder*, Apr. pp. 234–237
High-resolution camera, automatic-exposure control for, *Economou*, *Luban* and *Mehr*, Apr. pp. 249–251
Lenticular-plate cinemicrograph and image dissection process, analytical evaluation of, *Huggins*, Aug. pp. 523–526
Missile photography, atmospheric limitations on, *Duntley*, Apr. pp. 231–233
Missile photography, discussion, *Lipton*, Moderator, Apr. pp. 252–255
Missile testing, optical instrumentation for, symposium, *Lipton*, Apr. p. 225
Objects against a sky background, detection and recording of, visibility defined, *Martz*, Apr. pp. 228–233
Optical tracking instrumentation (cinetheodolites, tracking telescopes), *Schendel*, Apr. pp. 237–241
Optics, atmospheric, *Schepler*, Apr. pp. 225–227
Photographic instrumentation at the Air Proving Ground Center, *Schepler*, Apr. pp. 246–247
Rattlesnake strike, study of by time magnification, *Dunton* and *Lester*, Feb. pp. 65–68
Self-luminous events, color exposure for high-speed photography of, *Lohse*, Sept. pp. 567–571
Tracking mount system for a missile test range, ultra-precision, design and operational philosophy for, *Clemente*, Apr. pp. 242–245

HISTORICAL

The Adventure of Technicolor, *Kalmus*, Dec. pp. 829–830
History of motion pictures, annotated list of articles pertaining to (including some historical references on television), *Krainock*, Nov. pp. 771–775
Joseph T. Tykociner: pioneer in sound recording, *McCullough*, Aug. pp. 520–521
Tykociner's sound picture contributions, notes and reminiscences, *Aiken*, Aug. pp. 521–523

HONORS and AWARDS (See SOCIETY ACTIVITIES)

INSTRUMENTATION (See HIGH-SPEED PHOTOGRAPHY)

LABORATORY PRACTICE (See also PRINTERS and PRINTING)

General

Film-cleaning drum, powered, *Brueggemann*, Oct. pp. 686–688
Films for television, laboratory practices on, Recommended by The Association of Cinema Laboratories, Jan. pp. 6–7
Magnetic tape, ¼-in. synchronized with perforated motion-picture film, studio type and portable type systems, *Kennedy*, Feb. pp. 95–97
Silver-recovery apparatus for operation at high-current densities, *Cedrone*, Mar. pp. 172–174

Processing

Dye stability, Eastman Color Print Film, *Horowitz* and *Weller*, June pp. 401–404
Film-processing machine of flexible characteristics, *Moon* and *Everest*, Nov. pp. 758–762
Static markings on motion-picture film, causes and prevention of, *Kisner*, Aug. pp. 513–517

LENSES (See OPTICS)

LETTERS TO THE EDITOR

16 mm professional film—a proposal, *Lumley*, July p. 487
Stereophonic sound, magnetic/optical, *Guy; Maurer; Lewin;* Apr. pp. 255–256
Television Picture-Area Losses, *Chipp; Freeman;* May p. 343

LIGHTING AND LAMPS

Cold mirrors for projection heat control, *Balzers Laboratories*, Mar. pp. 1[illegible]
Photometric performance of incandescent filament lighting units used in theatre and television production, recommended practice for reporting, Joint I.E.S.—S.M.P.T.E. Committee on Equipment Performance Ratings, Sept. pp. 606–610
Screen-illumination readings, method of averaging, *Hill*, Mar. pp. 144–148
Tungsten filament lamps, high-wattage, for motion-picture and television studios, design improvements in, *Leighton* and *Makulec*, Aug. pp. 530–533
Xenon-arc projection lamp, *Reese*, June pp. 392–396
Xenon high-pressure lamps in motion-picture theaters, *Ullfers* (Abridged by *Hurd*), June pp. 389–392

NEW PRODUCTS AND DEVELOPMENTS (brief items)

In Jan., pp. 48-62
Technirama, wide-screen system, Technicolor Corp.
Spectra Professional exposure meter, Photo Research Corp.
Camera Pan and Tilt Head Type III, W. Vinten, Ltd.
The 1958 Kinevox-Hallen Model 616
Motor-driven 35mm cutter, H. L. Instrument Co.
Freon-TF solvent, film cleaner, E. I. du Pont
New Kodak Film Cleaner
Tuff Coat, noninflammable film cleaner, Nicholson Products Co.
The SM. 2, Genarco Slide projector, 70-slide changer
A 9mm positive projector carbon, National Carbon Co.
Honeycomb light-directional screen, Hexcel Products, Inc.
WB-30 lens centering tester, Wilhelm Bothner & Co.
Emcor Modular Enclosure System, The Elgin Metalformers Corp.
Tewe Model "C," zoom-type viewfinder, Camera Equipment Co.
Model R-15 Combination Reversal and Negative-Positive Processor, Filmline Corp.
Aiglonne 16mm Black-and-White Reversal, daylight developing machine, The Andre Debrie Mfg. Corp.
Magnetic soundhead adaptation for Arriflex 16mm camera, Rank Precision Industries
Ultra-high-speed camera, Electro-Optical Systems Inc.
CTI Supertester Model 180, tape-programmed tester, California Technical Industries Div.
Bludworth Marine Underwater TV Camera
Color TV Camera, General Electric
45,000-w UHF broadcast transmitter, General Electric
Time-lapse drive unit for use with Cine Kodak Special I or II Camera, The Electro-Mechanical Development Co.
Equipments for use in educational television, RCA
New Current Governors, North Hills Electric Co.
Electronic storage display panels, RCA
Directionalized VHF helical antenna, General Electric Co.
Shockley 4-layer npnp Silicon Diode, 2-terminal switching device, Shockley Semiconductor Laboratory
"Twistor," an experimental model of a memory device, Bell Telephone Laboratories
Philco Exicon, electronic instrument for reading x-ray negatives

In Feb., pp. 120-127
10,000-w spotlight lamp, General Electric Co.
Tru-Flector, Sylvania Electric Products Inc.
Adaptation of the Weinberg-Watson Kodak Analyst Projector, Camera Equipment Co.
1000-ft Arri Blimp, for Arriflex 35, Kling Photo Corp.
"Magic Mylar Sprocketed Transparent Splicing Tape," for butt-splicing 16mm and 35mm film, Florman & Babb
Electric eye mechanism of Bell & Howell 290 EE 8mm camera, 90-day endurance test
Lanco Electronic Relay, for laboratory water baths, Arthur S. LaPine & Co.
Stereo-Magnemite, self-contained stereophonic tape recorder, Amplifier Corp. of America
Filmline R-90 Processor, processor for 16mm reversal, negative and positive film.
16mm reversal black-and-white film, for use in tissue culture, Gevaert Co. of America
Photographic reconnaissance system, Fairchild Camera and Instrument Corp.
Multidata camera Model III B, Flight Research Inc.
Space Technology Laboratories, Ramo-Wooldridge Corp.
United Testing Laboratories, United Electrodynamics
A system for transmitting pictures over telephone lines, General Electric Co.
Closed-circuit color TV system installed at underground headquarters of SAC, Offcut Airforce Base, RCA
"Pure-picture" 21-in. TV monitor, RCA
An animation process, Colortech Films
Black-background screen, Allen B. Du Mont Laboratories, Inc.

In Mar., pp. 210-220
First bilingual drive-in theatre in world, Loew's Metro
Chroma-Key, electronic color "process photography", RCA
Black-and-white film process for color television, Bryg, Inc.
Triad Color Control, 16mm reversal-additive printing process, Southwest Film Laboratories
Movielab Color Corp., new film processing laboratory
Installation of Westrex sound recording system, Byron, Inc.
Sellevision unit, for filmed programming, Hallamore Electronics Co.
OMD 135 magnetic reproducer, Reeves Equipment Corp.
Flutter meter, Amplifier Corp. of America
Super Studio Zoomar lens
Bell & Howell-Angenieux Zoom Lens
Charactron shaped-beam tube, Type C19Q, Stromberg Carlson
Balanced Pan and Tilt Head for Vidicon TV Cameras and a 110-v a-c Synchronous Stop-Motion Motor for the Maurer Camera, Camera Equipment Co.
28-lb viewfinder TV camera chain, General Precision Laboratory, Inc.
Automatic shutter for motion-picture printers, Electronic Systems of Illinois, Inc.
Tape Punch and a Tape Duplicator, California Technical Industries
The Dial-Matic Perforator, Electronic Systems of Illinois, Inc.
EMT, a portable echo chamber, Hi-Fi Headquarters
NAVA Membership List and Trade Directory
Ultrasonic recorder, Argonne National Laboratory
The Strobotac, for measuring cyclic motion, General Radio Co.
Lustro-Chrome Vernier Caliper, for reading in poor light, The George Scherr Co.
Kodak Linagraph Direct Print Paper, photo recording paper, Eastman Kodak Co.
"Kodak Materials for Overhead Projection," Eastman Kodak Co.
Photodrawings, Eastman Kodak Co.
Simplex projectors manufactured by General Precision Laboratories

In Apr., pp. 278-284
Strong Jetarc Projection Lamp, a reflector-type projection lamp, Strong Electric Corp.
Magnetic Film recorder/reproducer, Model S7, Stancil-Hoffman Corp.
Automatic graphic high-speed power level recorder, Model S1-2, Sound Apparatus Co.
Type 1731 Junior Trombone, adjustable set wall arm, Mole-Richardson Co.
High-speed electrical eraser, RCA
114-ft traveling-wave TV transmitting antenna, RCA
Lumitron Infinite Preset System, lighting control system, Lumitron Div., Metropolitan Electric Mfg Co.
Outside Broadcast Television Camera Dolly, W. Vinten, Ltd.
Cinekad Fishpole Microphone Boom, Cinekad Engineering Co.

High-speed, intermittent-movement 16mm camera with pilot-pin registration, The D. B. Milliken Co.
50 Mylar T, thin-gauge Mylar polyester film, E. I. du Pont
"Satellite" tape, magnetic tape, Minnesota Mining and Manufacturing Co.
Aerojet-General Corp., closed-circuit TV system
Krylon Crystal-Clear Acrylic Spray

In May, pp. 350–364
Projectors, Model H (single shutter), Model HH (double shutter), Century Projector Corp.
Device for telecasting 16mm motion pictures, patent applied for, Alexander F. Victor Enterprises
Westrex Corp. purchased by Litton Industries, Inc.
New high-fidelity, 16mm sound motion-picture projector, Harwald Co.
New Filmosound 16mm motion-picture projector, Model 385, Bell & Howell
Bell & Howell Auto Load 8mm movie projector
Argus M500, 8mm projector, Argus Camera Div., Sylvania Electric Products, Inc.
750-w Kodak Showtime 8 Projector
Kodak Film Cleaner
Magnetic amplifier dimmer, Lumitron Div., Metropolitan Electric Mfg. Co.
New "Superior" 2 film, E. I. du Pont
Magnetic film striping machine, S.O.S. Cinema Supply Corp.
New type microphone, RCA
The Tele-Cinor 145mm $f/4.5$ for Camex Reflex camera, Karl Heitz Inc.
ITV Zoomar Mark II, lens for industrial TV cameras
Video tape recorder, British Broadcasting Corp.
Ampex VR-1000 Videotape Recorders purchased by Associated Rediffusion
Color conversion accessories available from Ampex Corp.
New line of magnetic tapes, RCA
Perforated $\frac{1}{4}$ in. tape with 8 mm or 16mm perforation, manufactured in France by Pyral
The 35mm Vinten HS-300 intermittent motion camera, available in U. S. through Benson-Lehner Corp.
Ace Clear-Vision Model II, tape splicer, Camera Equipment Co.
Automax Camera, Triad intervalometer and a Bell & Howell 70 KRM 16mm camera used in McDonnell F-101 Voodoo jet
Descriptions of 10 color processes for production of 35mm and 16mm release prints, Movielab Color Corp.
New Oxberry animation stand, Animation Equipment Corp.
Titling, animation and special effects camera stand and compound table, Warren Conrad Portman Co.
Small photoconductors, Clairex Corp.
Elwood Foto-Meter Model Z-4, Fotomatic Corp.
Four new 8mm electric-eye cameras, Bell & Howell

In June, pp. 430–438
Lighting units, General Electric Co., Ltd.
New dimmer combination, Mole-Richardson Co.
The Controlite dimmer bank, Ward Leonard Electric Co.
Pulsed Xenon Arc Lamp (PXA), General Electric, incorporated in a line of lighting equipment, American Speedlight Corp.
The TN Tempo Regulator (formerly Acoustical Time Regulator), Tele-Norm Corp.
The Pye Transhailer, lightweight electronic megaphone, Camera Equipment Co.
Stereo Magnecordette and P-75 Editor II, two new recording instruments, Magnecord Div., Midwestern Instruments Inc.
The Trickoma II, optical printer for making copies from 35mm or 16mm film
Lightweight metal cradle, Karl Heitz Inc.
Electron tube ($\frac{1}{8}$ in. in diameter by $\frac{1}{8}$ in. thick) developed by General Electric Research Laboratory
Two-terminal passive semiconductor component, Bell Telephone Laboratories
AIM Model C-125, a line of small electromagnetic clutches, Autotronics Inc.
Tele-Trol System for reception and redistribution of TV signals, Jerrold Electronics Corp.
Splicing tape and leader, Minnesota Mining and Mfg. Co.
General Electric regional headquarters for television and radio equipment opened in Syracuse, N. Y.
Breakaway glass — all types, Arden Inc.
AKG Model C-12, a polydirectional condenser microphone, distributed in U. S by Camera Equipment Co.
Instantaneous Electronic Color-Film Analyzer, Hazeltine Research Corp.
V-114A, automatic program system, Foto-Video Laboratories Inc.
Silver Recovery Unit, Model O-57, Oscar Fisher Co.
Sturelab XI, a 176 page catalogue, S.O.S. Cinema Supply Corp.
The Color Labmaster, color film processing machine, Houston Fearless Corp.
Intervalometer for Arriflex 16 cameras, Kling Photo Corp.
A 3-stage microphone preamplifier, 1556A, Altec Lansing Corp.
High-speed head for continuous black-and-white printing at 200 ft/min, Fish-Schurman Corp.

In July, pp. 502–510
Heat-Reflecting Filters in Carbon-Arc Projection Systems, a paper submitted for, but not read at 83rd Convention
Miniature TV camera, Dage Television Div., Thompson Products Inc.
Closed-circuit TV installed in N. Y. Central Railroad yards, Elkhart, Ind., by RCA
Automatic programming equipment designed for a TV station break, RCA
Exposure time of 0.01 μsec with Kerr cell electro-optical shutter and pulse generator circuit, Research and Advanced Development Div., Avco Mfg. Corp.
Audipage, for two-way closed-circuit communication, Philco Corp.
Precision wire-wound resistors catalogue, 14RC, Cinema Engineering
The Tel-Amatic 16mm printer, S.O.S. Cinema Supply Corp.
Artiscope, "illustration in animation by automation," Illustrated Films Inc.
Projection Optics Co. purchased by Charles Beseler Co.
Transistor action at a semiconductor/electrolyte interface modulated by an electrical field described by Bell Telephone Laboratories
The Magneloop series of continuous-loop magnetic tape recorders, Amplifier Corp. of America
"16mm Kodak Movie Films—Data and Selection"
Model 6800, an electric slide changer, Genarco Inc.
Industrial Vidicon Camera Channel, Type BD-871, The Canadian Marconi Co.

In August, pp. 553–558
Scotchlite, Minneapolis Mining and Mfg. Co.
Cardioid condenser microphone, Altec Lansing Corp.
Ott-Lovick High-Efficiency Air Squeeges, BHO Instruments Inc.
Houston Fearless Labmaster 16mm black-and-white film processor
Philco Corp., special type of gas Maser
Kodak Prepaid Processing Mailers
"Printing Color Negatives," Eastman Kodak Co.
Model 1216, portable film recording system, Hallen Electronics Co., Div. of Schoen Products Co.
Scotch brand reel, Minnesota Mining and Mfg. Co.
Automatic bulk tape eraser, Ampex Corp.
Professional tape recorders, Presto Recording Corp.
Rangertone, Inc., catalog of synchronous $\frac{1}{4}$-in. magnetic recording equipment.
Story of Magnetic Recording, Minnesota Mining and Mfg. Co.
Debrie 16 auxiliary projector, supplementary fitting to 35mm projector
Electronic enlarger, LogEtronics, Inc.
RCA TK-15 vidicon TV camera
GPL Precision Television System, Model PD-250, catalog
Low-priced closed-circuit TV system, Allen B. Du Mont Laboratories, Inc.
Transistorized synchronizing generator for television stations, General Electric
Portable oscilloscope, Waterman Products Co.

In Sept., pp. 650–654
Automatic printer shutter control and printer roller gate, Bell & Howell
Rapid spray processing machine, Model S-150R, for 16mm and 35mm films, Filmline Corp.
Tuff Coat, antistatic material for cleaning film, Nicholson Products Co.
Oxberry Animation Stand (Model S) distributed exclusively in Eastern United States by Camera Equipment Co.
Animation compound, Warren Conrad Portman Co.
Quadlite, 10 in. square floodlight, Mole-Richardson Co.
Animation Equipment catalog, Bowlds Engineering
Remote-control pan and tilt assembly, Camera Equipment Co.
Mobile film developing machine, Motion Picture Enterprises, Inc.
5.7mm $f/1.8$ Kinoptic Apochromat lens, Karl Heitz, Inc.
Meaning of exposure indexes, Eastman Kodak Co.
Photoelectric 8mm camera, Paillard, Inc.
398A Special Filmosound, Bell & Howell Co.
TT-2BH, transmitter for medium-coverage TV stations, RCA
Model 1150 Automatic Picture and Sound Generator, B&K Mfg. Co.
Giantview, TV projector which projects images up to a size of 12 by 15, Tela Electronics
Grundig Miniature TV Camera, distributed by L. M. Bleackley
High pass-low pass filter, Model 420P, Allison Laboratories, Inc.
Cable tester, California Technical Industries, Division of Textron, Inc.
Semiautomatic Alignment Kit, Canadian Marconi Co.
Photo-Sonics rotary-prism high-speed recording camera–improved version–Traid Corp.
EOTS Equipment, J. W. Fecker, Inc.
Thinform Model FDTF-001, compact and rugged 16mm data camera, Fairchild Data Devices Corp.
Compressed Air Loudspeaker (CAL), RCA
The Flip, automatic microfilm searching machine, Benson-Lehner Corp.
New "Scotch" brand magnetic tape, Minnesota Mining and Mfg. Co.
Microphone Facts, Electro-Voice, Inc.
Gevaert Cine Phase "26" 16mm reversal black-and-white film, now available.

In Oct., pp. 715–719
Ampex Videotape Splicer
Raytheon Mfg. Co. dark tunnel
Loudspeakers, Racon Electric Co.
Multidata M-3 16mm film magazine, Flight Research Inc.
Traid 560 Fotomatic instrumentation camera
Continuous Writing Streak Camera Model 194, Beckman & Whitley
Robot Recorder, 35mm camera for photographic registration, Karl Heitz Inc.
Schott Interference Band Filters, Fish-Schurman Corp.
Macbeth Quantalog, a photometer
TV camera pedestal, W. Vinten Ltd.
NCE 35mm Viewer, National Cine Equipment Inc.
Trigger-grip handle for Filmo 70 series cameras, National Cine Equipment Co.
New lens for Arriflex 16mm and 35mm cameras, Kling Photo Corp.
Camera stabilizer, Howard Dearborn Inc..
Gossen photoelectric exposure meters, 10-page folder, Kling Photo Corp.
Anscochrome and Super Anscochrome film, information on filters, Ansco
Ampro Super Stylist 16mm sound film projectors, Graflex Inc.

Brownie Scopesight Movie Camera, Eastman Kodak Co.
Film editing outfit for amateurs, Eastman Kodak Co.

In Nov., pp. 796–799
Rap-Edit Sync Point Shifter Magnetic Recorder, D'Arcy Magnetic Products
Studio Quik Splicer, Hudson Photographic Industries Inc.
Electric automatic splicer, Prestoseal Mfg. Co.
Fairchild Data Reader
Spectra small TV camera, Photo Research Corp.
Navy's icebreakers photographed by TV cameras in helicopters, equipment by Philco Corp.
"Light chopper" to produce pulses of light, Westinghouse Research Laboratories
Super Tru-Flector lamp, Sylvania Electric Products Inc.
Vacuum forming machine, Auto-Vac Co.

OBITUARIES

Brown, Freeman H., Feb. p. 114
Butler, John W., Nov. p. 788
Carver, Emmett K., Sept. p. 636
Gardenhire, Hervey T., Apr. p. 272
Hance, Paul D., Jr., Apr. p. 272
Hudders, James B., Apr. p. 273
Kennedy, Edward P., July p. 498
Lasky, Jesse L., Apr. p. 273
Pathe, Charles, Oct. p. 701
Santini, Carlos Connio, May p. 348
Solbert, Oscar N., July p. 498
Szeglin, Stephen, Nov. p. 788
Toulon, Pierre M. G., Oct. p. 701
Warner, Harry M., Sept. p. 637

OPTICS

Camera lenses, 35mm, *Cook*, Aug. pp. 534–536
Flying camera stations, *Kinder*, Apr. pp. 234–237
Lenticular color-film process, optics of, *Kingslake*, Jan. pp. 8–13
Missile photography, atmospheric limitations on, *Duntley*, Apr. pp. 231–233
Motion-picture projector, integral optical-mechanical system, *Rosenberger*, June pp. 378–384
Objects against a sky background, detection and recording of, visibility defined, *Martz*, Apr. pp. 228–233
Optical tracking instrumentation (cinetheodolites, tracking telescopes), *Schendel*, Apr. pp. 237–241
Optics, atmospheric, *Schepler*, Apr. pp. 225–227
Tracking guided missiles with optical devices, application of television to, *Roberts*, July pp. 475–477
Tracking mount system for a missile test range, ultra-precision, design and operational philosophy for, *Clemente*, Apr. pp. 242–245
Vidicon camera lenses, *Cook*, Sept. pp. 596–598
Vidicon-type cameras, new series of lenses, *Hayes*, Sept. pp. 593–595
Zoom lenses for closed-circuit television, *Back*, Sept. pp. 598–600

OTHER SOCIETIES

Association of Cinema Laboratories, Apr. pp. 268, 270
Photography's Place in Space, speech, *McMaster*, Society of Photographic Scientists and Engineers, Annual Banquet, Nov. p. 778
Society of Photographic Instrumentation Engineers, Apr. p. 266; Oct. p. 696
Society of Photographic Scientists and Engineers, Apr. p. 266–268

PHOTOMETRY (see also LIGHTING, and OPTICS)

Photometric performance of incandescent filament lighting units used in theatre and television production, recommended practice for reporting, Joint I.E.S.-S.M.P.T.E. Committee on Equipment Performance Ratings, Sept. pp. 606–610
Screen-illumination readings, averaging, *Hill*, Mar. pp. 145–148
Spectral characteristics of color screens, method for evaluation, *Weiss*, Sept. p. 605

PRINTERS AND PRINTING

Additive color system, new, for motion-picture photography, *Wheeler*, Nov. pp. 747–749
American Standard, Picture and Sound Apertures for Continuous Contact Printers for 35mm Release Prints with Photographic Sound Records, PH22.111-1958, June p. 412
American Standard, Scene-Change Cueing for Printing 16mm Motion-Picture Film, PH22.89-1958, June p. 411
Color-film analyzer, instantaneous electronic, *Loughlin, Page, Bailey, Hirsch, Miller* and *Giarraputo*, Jan. pp. 17–26
Color printing, glass filter for, *White* and *Lovick*, Jan. pp. 29–31
Color timer for motion-picture films, a new, *Stafford* and *Baumbach*, Feb. pp. 81–83
Color timing calculating machine, *Keene, Sant* and *Clifford*, Nov. pp. 763–767
Color timing method and calculator for subtractive motion-picture printers, *Keene*, June pp. 404–408
Dye stability, Eastman Color Print Film, *Horowitz* and *Weller*, June pp. 401–404
Geneva scene-change mechanism, subtractive color printer with, *Brueggemann*, Nov. pp. 769–771
Motion-picture films immersed in a liquid, printing of, Pt. III — evaluation of liquids, *Delwiche, Clifford* and *Weller*, Oct. pp. 678–685
Motion-picture printers, electromechanical light valve for, *Herrnfeld*, Jan. pp. 27–28
Newton's rings, preventing formation of during contact printing of motion-picture film, *Osborne*, Mar. pp. 169–171
Optical printer, newly designed, *Palen*, Feb. pp. 98–102
Printer light selector, automatic for Bell & Howell D and J Printers, *Wargo, Little* and *Baumbach*, Feb. pp. 78–80
Sensitometer, use of motion-picture printer as, *Gale* and *Graham*, Feb. pp. 84–86
Spectral characteristics of color screens, method for evaluation, *Weiss*, Sept. p. 605

PRODUCTION

Additive color system, new, for motion-picture photography, *Wheeler*, Nov. pp. 747–749
Multi-voice films for international television, future trends in, *Shelly*, Mar. p. 143
Television viewfinder, improved, for motion-picture production, *Freund*, Nov. pp. 745–746

PROGRESS COMMITTEE REPORT

Progress Committee Report for 1957 (295 refs., 100 illus.), *Lloyd Thompson, Committee Chairman*, May pp. 289–343

PROJECTION

General

American Standard (Revision of Z22.23-1941) 8mm Motion-Picture Projection Reels, PH-22.23-1958, Aug. p. 537
American Standard, Picture-Sound Separation in 16mm Magnetic Sound Projectors, PH22.-112-1958, June p. 412
American Standard (Revision of Z22.28-1946) Focal Lengths and Markings of 35mm Motion-Picture Projection Lenses, PH22.28-1958, June p. 409
Motion-picture projector, integral optical-mechanical system, *Rosenberger*, June pp. 378–384
TV film programs, motion-picture laboratory projection facilities for servicing, *Kloepfel*, Oct. pp. 676–678

Television

Color television projection, medium screen, *Bendell* and *Neely*, Mar. pp. 166–168
Cuing, automatic, of television film projectors, *Melchionni*, Feb. pp. 92–94
Projection equipment large-screen television, survey of, *Gillette*, Mar. pp. 164–166

16mm and 8 mm

Projector, Siemens dual-strip 16/16, with synchronous motor (Abridgment), *Kronenberger*, July p. 486

PULL-DOWN MECHANISMS

Samuel B. Grimson, film pulldown mechanism based on a design by, *O'Grady*, June pp. 385–388

SCREEN BRIGHTNESS (see also ARCS, and LIGHTING)

Screen-illumination readings, averaging of, *Hill*, March pp. 144–148

SENSITOMETRY

Embossed kinescope recording film, devices for making sensitometric exposures on, *Crane* and *Evans*, Jan. pp. 13–16
Sensitometer, use of motion-picture printer as, *Gale* and *Graham*, Feb. pp. 84–86

SOCIETY ACTIVITIES

General

Convention Plans and Other Prospects, *Kreuzer*, June pp. 413–414
Education—A New Era Begins, *Mitchell*, Dec. pp. 828–829
High-speed photography activities (report), Apr. p. 264
Progress Report Volunteers, Oct. p. 696
Recollections and predictions, *Kreuzer*, Dec. pp. 826–827
Represented at 10th International Cinematography Engineering Congress, Oct. p. 698
SMPTE at TOA-TESMA-NAC Show, Feb. p. 108
A Writer–Producer Looks at SMPTE, *Brackett*, June pp 414–415

Awards and Citations

Academy Award presented SMPTE, Apr. p. 264
Adventure of Technicolor, *Kalmus*, Dec. pp. 829–830
Annual Awards, Announcement, Aug. p. 540
Awards at Convention, Announcement, Sept. p. 612
Awards Descriptions and Past Recipients, Apr. Pt. II, pp. 18–21
Presentation of Awards, Dec. pp. 836–847

Committees

Education course, Oct. p. 696
Education, East Coast, announcement, Jan. p. 38
Elections: Report, Nov. pp. 784, 786
Engineering activities, committee meetings at 83d Convention, Aug. p. 542
High-speed activities, Apr. p. 264
Meetings Schedule, 83d Convention, tentative, Mar. p. 177
Meetings Schedule, 84th Convention, tentative, Sept. p. 612
Progress, report, May pp. 289–343

Constitution and Bylaws

Apr. Pt. II, pp. 14–17

Conventions

85th, Announcements, Papers Program, Equipment Exhibit, Nov. p. 776, Dec. p. 831
84th, Report, Dec. pp. 831–836
84th, Advance Program, Sept. pp. 611–628; Announcements, Sept. p. 611, Aug. p. 540, July p. 488, June p. 415, May pp. 344–346
83d, Report, July pp. 488–494; Advance Program, Mar. pp. 177–198; Announcements, Feb. pp. 104, 106, Jan. p. 38

Engineering Activities

Report, Aug. p. 542

Financial Reports

Apr. Pt. II, p. 13

Membership and Subscriptions

Alphabetic List of Members, Apr. Pt. II, pp. 22–66
Deceased Members, Apr. Pt. II, p. 66
Directory, Announcements, Feb. p. 104, Jan. p. 38

Directory for Members, Apr. Part II, pp. 1–80
Directory, to be published biennially, Aug. p. 540
Errata—A Directory for Members (Apr. 1958, Pt. II) July p. 479
Geographic List of Members, Apr. Pt. II, pp. 67–80
New Members, Sept. pp. 640–648
Sustaining Members, Apr. Pt. II, back covers

Officers and Governors of the Society

Nomination of Officers, Aug. p. 540
Roster, Apr. Pt. II, pp. 4–6
SMPTE Elections, Nov. pp. 784, 786

Publications

Announcements: High-Speed Photography Vol. 6, Apr. p. 264; Television Bibliography, a 20-page listing of *Journal* articles since 1940.

Section Activities

Atlanta, Mar. p. 206; Aug. p. 548
Canadian, June p. 422; Aug. p. 548; Sept. p. 634
Chicago, Feb. p. 116; Mar. p. 204; June p. 422
Dallas-Ft. Worth, Mar. p. 204; June p. 424; Aug. p. 549
Hollywood, Feb. p. 119; June p. 424
New York, June p. 426; Aug. p. 549
Rochester, Feb. pp. 116, 118; Mar. p. 206; June p. 426
San Francisco, Feb. p. 118; Mar. p. 206; June p. 428; Aug. p. 549
Washington, June p. 428

Test Films (Slides)

SMPTE Color TV Test Slides, Mar. p. 177

SOUND RECORDING

General

American Standard, Four Magnetic Sound Records on 35mm Film, PH22.108-1958, June p. 411
Bilingual films, methods of translating, *Kosarin*, Mar. pp. 139–140
Joseph T. Tykociner: pioneer in sound recording, *McCullough*, Aug. pp. 520–521
Lip-synchronized sound recording, 16mm magnetic-optical sound projector used, *Askren* and *Dwyer*, Jan. pp. 32–34
Magnetic tape, ¼-syncronized with perforated motion-picture film, studio type and portable type systems, *Kennedy*, Feb. pp. 95–97
Recording system, portable sprocket type, magnetic tape or film, *Crane* and *Templin*, Nov. pp. 754–758
Tykociner's sound picture contributions, notes and reminiscences, *Aiken*, Aug. pp. 521–523

Magnetic

Magnetic recording media considerations for improving masters and dubs, *Tinkham*, Oct. pp. 662–665
Standardization, international, of magnetic sound on film–status report, *Townsley*, Dec. pp. 822–823
Stereophonic sound, magnetic/optical (letters to editor), *Guy; Maurer; Lewin;* Apr. pp. 255–256

Photographic

Photographic recording system, versatile, for studio use, *Brookes* and *Manley*, Oct. pp. 666–672
Variable-area sound recordings, photographic duplication of, *Finkle*, Aug. pp. 518–520

STANDARDS and RECOMMENDATIONS

See the specific subject headings or the list of standards published in 1958 on a later page of this Index. Also, see the Index to American Standards and SMPTE Recommended Practices which includes all standards now in effect.
~~Standardization, international, of magnetic sound~~ on film—status report, *Townsley*, Dec. pp. 822–823
Standardization, international, for motion pictures and films for television, *White*, Dec. pp. 819–821
Standardization, SMPTE contributions to in the U.S., *Kolb*, Dec. pp. 824–826

STUDIOS

Human engineering problems in television control room design, *Pores*, Oct. pp. 672–675
Sound stage, motion-picture production, design and construction of, *Larsen*, Apr. pp. 260–263

TELEVISION

Cameras, Pickup Equipment (including Lenses)

Cuing, automatic, of television film projectors, *Melchionni*, Feb. pp. 92–94
Pickup tube performance with slow scanning rates, *Shelton* and *Stewart*, July pp. 441–451
Rugged environmental conditions, TV system for use in, *Day* and *Pike*, July pp. 470–472
Vidicons, beam-landing errors and signal output uniformity of, *Neuhauser* and *Miller*, Mar. pp. 149–153
Vidicon camera lenses, *Cook*, Sept. pp. 596–598
Vidicon, one-inch, developmental improved for television cameras, *Miller* and *Vine*, Mar. pp. 154–156
Vidicon-type cameras, series of lenses for, *Hayes*, Sept. pp. 593–595
Zoom lenses for closed-circuit television, *Back*, Sept. pp. 598–600

Closed-Circuit

Color television projection, medium screen, *Bendell* and *Neely*, Mar. pp. 166–168
Projection equipment, large-screen television, survey of, *Gillette*, Mar. pp. 164–166
Rocket engine tests, television viewing of (remotely operated system), *Mitchell*, July pp. 473–474
Visual amplification, *Schlafly*, Mar. pp. 163–164

Color

Color-television images and perception of color detail, on the quality of, *Schade*, Dec. pp. 801–819
Color television projection, medium screen, *Bendell* and *Neely*, Mar. pp. 166–168

Films

Films for television, laboratory practices on, Recommended by The Association of Cinema Laboratories, Jan. pp. 6–7
Film in television, *Ross*, June pp. 374–378
Film standards, monochrome television, *Benson* and *Whittaker*, Jan. pp. 1–5
Lenticular color-film process, optics of, *Kingslake*, Jan. pp. 8–13

General

Announcing techniques, automatic, for television stations, *Isberg*, Feb. pp. 87–91
Gray-scale equivalent of colors used in live and filmed television and scenic and graphic art, method of controlling, *Wagner*, June pp. 369–373
TV film programs, motion-picture laboratory projection facilities for servicing, *Kloepfel*, Oct. pp. 676–678

International

Bilingual films, methods of translating, *Kosarin*, Mar. pp. 139–140
Bilingual telecasting in Canada, case history, *Landry*, Mar. pp. 141–142
International television and bilingual films, (Preface), *D'Arcy*, Mar. p. 129
International television broadcasting, problems of, *Bridgewater*, Mar. pp. 129–133
Multi-voice films for international television, future trends in, *Shelly*, Mar. p. 143
Transatlantic television, NARCOM plan for, and other wideband telecommunication services, *Halstead*, Mar. pp. 134–138

Lighting

Tungsten filament lamps, high-wattage, design improvements in for motion-picture and television studios, *Leighton* and *Makulec*, Aug. pp. 530–533

Military

Aircraft instrumentation, new directions, (Preface), *Hoover*, July p. 452
Closed-loop television system for aircraft, *Flacco*, July pp. 477–479
Parade control and field exercises, television for, *Dakin*, *Martin*, *Bue* and *Smith*, July pp. 461–463
Pickup tube performance with slow scanning rates, *Shelton* and *Stewart*, July pp. 441–451
Recordings (kinescope), technical and production problems in military television, *Gray*, July pp. 463–464
Research and development, Army television (special requirements for military equipment), *Huber* and *Le Vino*, July pp. 465–469
Rocket engine tests, television viewing of (remotely operated system), *Mitchell*, July pp. 473–474
Television, military uses of, (Preface), *Batsel*, July p. 441
Thin cathode-ray tube, development of, *Aiken*, July pp. 452–455
Tracking guided missiles with optical devices, application of television to, *Roberts*, July pp. 475–477
Transparent cathode-ray screens, development and applications, *Feldman*, July pp. 455–460

Picture & Quality

Anamorphic television circuit requirements, *Cawein*, Apr. pp. 257–259
Color-television images and perception of color detail, on the quality of, *Schade*, Dec. pp. 801–819
Optical sine-wave spatial spectrum of television image display devices, a method of measuring, *Schade*, Sept. pp. 561–566
Picture quality control, color television, stabilized monitor for, *Gloystein* and *Kellaway*, Mar. pp. 157–162
Television picture area losses (letters to editor), *Chipp*, *Freeman*, May p. 343

Projection

Color television projection, medium screen, *Bendell* and *Neely*, Mar. pp. 166–168
Projection equipment, large-screen television, survey of, *Gillette*, Mar. pp. 164–166

Recording

Additive color system, new, for motion-picture photography, *Wheeler*, Nov. pp. 747–749
Editing video-tape recordings, electronic marking and control for rapid location of vertical blanking area, *Roizen*, Nov. pp. 732–733
Los Angeles Convention Discussion, Nov. pp. 743–745
Processing amplifier in the Ampex Videotape Recorder, *Dolby*, Nov. pp. 726–729
Recordings (kinescope), technical and production problems, *Gray*, July pp. 463–464
Signal translation through the Ampex Videotape Recorder, *Anderson*, Nov. pp. 721–725
Splicing video tape, factors affecting, *Machein*, Nov. pp. 730–731
Video recording, high-fidelity, using ultrasonic light modulation, *Levi*, Oct. pp. 657–661
Video-tape recorders, interchangeability of, *Ginsburg*, Nov. pp. 739–743
Washington, D.C. Convention Discussion, Nov. pp. 737–739

Studio Production

Human engineering problems in television control room, *Pores*, Oct. pp. 672–675

THEATERS

Exhibition, new horizons in, *Schlanger*, Aug. p. 527
Great Britain, National Film Theatre, *Scott*, Aug. pp. 527–530

VIDEO TAPE

Magnetic tape for video recording, *von Behren*, Nov. pp. 734–737

INDEX TO AUTHORS—January–December 1958 • Volume 67

Aiken, Joseph E. Technical Notes and Reminiscences on the Presentation of Tykociner's Sound Picture Contributions, Aug. pp. 521–523

Aiken, William Ross, Development of the Thin Cathode-Ray Tube, July pp. 452–455

Anderson, Charles E., Signal Translation Through the Ampex Videotape Recorder, Nov. pp. 721–725

Askren, Lee T., and **Dwyer, Raymond J.**, Recording Lip-Synchronized Sound Using a 16mm Magnetic-Optical Sound Projector, Jan. pp. 32–34.

Association of Cinema Laboratories, Laboratory Practices on Films for Television, Jan. pp. 6–7

Ayling, Russell J., and **Hatch, Arthur J.**, Improvements in the Blown Arc for Projection, Oct. pp. 693–695

Back Frank G., Zoom Lenses for Closed-Circuit Television, Sept. 598–600

Bagby, John P., See **La Rue, Mervin W., Jr., et al.**

Bailey, William F., See **Loughlin, Bernard D., et al.**

Balzers Laboratories, Cold Mirrors for Projection Heat Control, Mar. pp. 175–177

Batsel, Max C., Military Uses of Television, July p. 441

Baumbach, H. L., See **Stafford, J. W.**

——, See also **Wargo, Lorand, et al.**

Bendell, S. L., and **Neely, W. J.**, Medium Screen Color Television Projection, Mar. pp. 166–168

Benson, K. B., and **Whittaker, J. R.**, Monochrome Television Film Standards, Jan. pp. 1–5

Brackett, Charles, A Writer Looks at SMPTE, June p. 414

Bridgewater, T. H., Problems of International Television Broadcasting, Mar. pp. 129–133

Brookes, G. A., and **Manley, H. A.**, A Versatile Photographic Recording System for Studio Use, Oct. pp. 666–672

Brueggemann, Harry, A Powered Film-Cleaning Drum, Oct. pp. 686–688

——, Subtractive Color Printer With Geneva Scene-Change Mechanism, Nov. pp. 769–771

Bue, Paul A. J., See **Dakin, Hollis, et al.**

Bushman, Stephen F., See **La Rue, Mervin W. Jr., et al.**

Cawein, Madison, Anamorphic Television Circuit Requirements, Apr. pp. 257–259

Cedrone, Nicholas J., A Silver-Recovery Apparatus for Operation at High Current Densities, Mar. pp. 172–174

Chipp, Rodney D., Letter to the Editor: Television Receiver Picture-Area Losses, May p. 343

Clemente, John A., A Design and Operational Philosophy for an Ultra-Precision Tracking Mount System for a Missile Test Range, Apr. pp. 242–245

Clifford, James D., See **Delwiche, Donald A.**

——, See **Keene, G. T., et al.**

Conger, Richard R., Ultra-Cold Weather Photography, Jan. pp. 35–37

Cook, Gordon Henry, 35mm Camera Lenses, Aug. pp. 534–536

——, Vidicon Camera Lenses, Sept. pp. 596–598

Crane, Edward M., and **Evans, C. H.**, Devices for Making Sensitometric Exposures on Embossed Kinescope Recording Film, Jan. pp. 13–16

Crane, G. R. and **Templin, E. W.**, A Portable Sprocket-Type Magnetic Tape or Film Recording System, Nov. pp. 754–758

Dakin, Hollis, Martin, Frederick L., Bue, Paul A. J. and **Smith, Jack R.**, Television for Parade Control and Field Exercises, July pp. 461–463

D'Arcy, Ellis W., Program Topic Chairman, International Television and Bilingual Films, Introduction to Five Papers, Mar. p. 129

Day, John P. and **Pike, Frank R.**, Television for Use Under Rugged Environmental Conditions, July pp. 470–472

Deane, Edward H., See **Turner, John R., et al.**

Delwiche, Donald A., Clifford, James D., and **Weller, William R.**, Printing Motion-Picture Films Immersed in a Liquid — Part III: Evaluation of Liquids, Oct. pp. 678–686

Dolby, Ray M., The Video Processing Amplifier in the Ampex Videotape Recorder, Nov. pp. 726–729

Duntley, Seibert Q., Atmospheric Limitations on Missile Photography, Apr. pp. 231–233

Dunton, Sam C., and **Lester, Henry M.**, Time-Magnification Study of a Rattlesnake Strike, Feb. pp. 65–68

Dwyer, Raymond J., See **Askren, Lee T.**

Economou, George, Luban, Vladimir, and **Mehr, Morton**, Automatic-Exposure Control for a High-Resolution Camera, Apr. pp. 249–251

Evans, C. H., See **Crane, Edward M.**

Everest, F. Alton, See **Moon, Irwin A.**

Fassett, D. W., Kolb, F. J., Jr. and **Weigel, E. M.**, Practical Film Cleaning for Safety and Effectiveness, Sept. pp. 572–589

——, Errata for Sept. *Journal*, Nov. p. 768

Feldman, Charles, Development and Applications of Transparent Cathode-Ray Screens, July pp. 455–460

Finkle, J. F., Photographic Duplication of Variable-Area Sound Recordings, Aug. pp. 518–520

Fischer, Rudolf and **Ploke, Martin**, Heat-Reflecting Filters in Carbon-Arc Projection Systems, July pp. 502–504

Flacco, Arthur F., Airborne Closed-Loop Television System, July pp. 477–479

Forrest, John L., 16mm Super Anscochrome Films, Oct. pp. 691–693

Freeland, Stanley R., See **La Rue, Mervin W., Jr., et al.**

Freeman, Otis, See **Chipp, Rodney D.**

Freund, Karl, Improved Television Viewfinder for Motion-Picture Production, Nov. pp. 745–746

Gale, Robert O., and Graham, John J., Use of a Motion-Picture Printer as a Sensitometer, Feb. pp. 84–86

Gephart, William E., Chairman, Laboratory Practices on Films for Television, Jan. pp. 6–7

Giarraputo, Leonard, See **Loughlin, Bernard D., et al.**

Gillette, Frank N., Survey of Large-Screen Television Projection Equipment, Mar. pp. 164–166

Ginsburg, Charles P., Interchangeability of Videotape Recorders, Nov. 739–743

Gloystein, E. E., and **Kellaway, N. P.**, A Stabilized Monitor for Color Television Picture Quality Control, Mar. pp. 157–162

Graham, John J., See **Gale, Robert O.**

Gray, Norman, Technical and Production Problems in Military Television Recordings, July pp. 463–464

Grunwald, Robert and **Wallace, Richard**, Automatic Television Film Editing, June pp. 397–400

Guy, Steven A., Letter to the Editor: Magnetic/Optical Stereophonic Sound, Apr. pp. 255–256

Halstead, William S., The NARCOM Plan for Transatlantic Television and Other Wide-band Telecommunication Services, Mar. pp. 134–138

——, Errata for Mar. *Journal*, Apr. p. 256

Hatch, Arthur J., See **Ayling, Russell J.**

Hayes, John D., A New Series of Lenses for Vidicon-Type Cameras, Sept. pp. 593–595

Herrnfeld, Frank P., An Electromechanical Light Valve for Motion-Picture Printers, Jan. pp. 27–28

Hill, Armin J., Averaging Screen-Illumination Readings, Mar. pp. 144–148

Hirsch, Charles J., See **Loughlin, Bernard D., et al.**

Hoover, George W., New Directions in Aircraft Instrumentation, July p. 452

Horowitz, Paul and **Weller, William R.**, Some Considerations of Eastman Color Print Film Dye Stability, June pp. 401–404

Huber, William A., and **Le Vino, Richard B.**, Army Television Research and Development, July pp. 465–469

Huggins, Charles M., An Analytical Evaluation of the Lenticular-Plate Cinemicrograph and the Image-Dissection Process, Aug. pp. 523–526

Hurd, Y. G., Abstract of Xenon High-Pressure Lamps in Motion-Picture Theaters by **Heinz Ulffers**, June pp. 389–392

Isberg, R. A., Automatic Announcing Techniques for Television Stations, Feb. pp. 87–91

Johnson, Eric C., Prolonging the Life of Motion-Picture Release Prints, Sept. pp. 590–592

Kalmus, Herbert T., The Adventure of Technicolor, Dec. pp. 829–830

Keene, G. T., A Color Timing Method and Calculator for Subtractive Motion-Picture Printers, June pp. 404–408

——, Errata for June *Journal*, Nov. p. 768

——, **Sant, A. J.**, and **Clifford, J. D.**, A Color Timing Calculating Machine, Nov. pp. 763–768

Kellaway, N. P., See **Gloystein, E. E.**

Kennedy, Edward P., A Studio-Type and a Portable-Type System for Synchronizing ¼-Inch Magnetic Tape With Perforated Motion-Picture Film, Feb. pp. 95–97

Kinder, Floyd A., Flying Camera Stations, Apr. 234–237

Kingslake, Rudolf, The Optics of the Lenticular Color-Film Process, Jan. pp. 8–13

Kisner, W. I., Causes and Prevention of Static Markings on Motion-Picture Film, Aug. pp. 513–517

Kloepfel, Don V., Motion-Picture Laboratory Projection Facilities for Servicing TV Film Programs, Oct. pp. 676–678

Kolb, Frederick J., Jr., SMPTE Contributions to Standardization in the U. S., Dec. pp. 824–826

——, See **Fassett, D. W., et al.**

Kosarin, Max G., Methods of Translating Used in Bilingual Films, Mar. pp. 139–140

Krainock, Mildred B., An Annotated List of Articles Pertaining to the History of Motion Pictures—1950–1956 (Including Some Historical References on Television), Nov. pp. 771–775

Kreuzer, Barton, Convention Plans and Other Prospects, June pp. 413–414

——, Recollections and Predictions, Dec. pp. 826–827

Kronenberger, Heinz, Siemens Dual-Strip 16/16 Projector With Synchronous Motor: Abstract, July p. 486

Landry, Jacques, A Case History of Bilingual Telecasting in Canada, Mar. pp. 141–142

Larsen, James A., Design and Construction of a Motion-Picture Production Sound Stage, Apr. pp. 260–263
La Rue, Mervin W., Jr., Bagby, John P., Bushman, Stephen F., Freeland, Stanley R. and **MacMillin, David M.**, A Direct-Drive Automatic Iris Control, Sept. pp. 600–604
Leighton, Leroy G. and **Makulec, Alfred**, Design Improvements in High-Wattage Tungsten Filament Lamps for Motion-Picture and Television Studios, Aug. pp. 530–533
Lester, Henry M., See **Dunton, Sam C.**
Levi, Leo, High-Fidelity Video Recording Using Ultrasonic Light Modulation, Oct. pp. 657–661
——, Addendum to Oct. *Journal*, Nov. p. 746
Le Vino, Richard B., See **Huber, William A.**
Lewin, George, See **Guy, Steven A.**
Lipton, Sidney M., Chairman and Moderator, Symposium and Discussion on Missile Photography, Apr. pp. 225, 252–255
Little, H. M., See **Wargo, Lorand, et al.**
Lohse, K. H., Color Exposure for High-Speed Photography of Some Self-Luminous Events, Sept. pp. 567–571
Loughlin, Bernard D., Page, Charles E., Bailey, William F., Hirsch, Charles J., Miller, Arthur J., and **Giarraputo, Leonard**, An Instantaneous Electronic Color-Film Analyzer, Jan. pp. 17–26
Lovick, Robert C., See **White, Richard L.**
Luban, Vladimir, See **Economou, George, et al.**
Lumley, R. Rees, Letter to the Editor: 16mm Professional Film — A Proposal, July p. 487

Machein, Kurt R., Factors Affecting the Splicing of Video Tape, Nov. pp. 730–731
MacMillin, David M., See **La Rue, Mervin W., Jr., et al.**
Makulec, Alfred, See **Leighton, Leroy G.**
Manley, H. A., See **Brookes, G. A.**
Martin, Frederick L. See **Dakin, Hollis, et al.**
Martz, E. P. Jr., Visibility: Detection and Recording of Objects Against a Sky Background, Apr. pp. 228–231
Maurer, John A., See **Guy, Steven A.**
McCullough, John B., Joseph T. Tykociner: Pioneer in Sound Recording, Aug. pp. 520–521
Mehr, Morton, See **Economou, George, et al.**
Melchionni, B. F., Automatic Cuing of Television Film Projectors, Feb. pp. 92–94
Miller, Arthur J., See **Loughlin, Bernard D., et al.**
Miller, L. D., and **Vine, B. H.**, Improved Developmental One-Inch Vidicon for Television Cameras, Mar. pp. 154–156
——, See also **Neuhauser, R. G.**
Mitchell, Jay P., Television Viewing of Rocket Engine Tests, July pp. 473–474
Mitchell, Maurice B., Education — A New Era Begins, Dec. pp. 828–829
Moon, Irwin A., and **Everest, F. Alton**, A Film-Processing Machine of Flexible Characteristics, Nov. pp. 758–762

Neely, W. J., See **Bendell, S. L.**
Neuhauser, R. G., and **Miller, L. D.**, Beam-Landing Errors and Signal-Output Uniformity of Vidicons, Mar. pp. 149–153

O'Grady, Frederick T., Film Pulldown Mechanism Based on a Design by Samuel B. Grimson, June pp. 385–388
Olson, Harry F., and **Preston, John**, The Electrostatic Uniangular Microphone, Nov. pp. 750–753
Osborne, Charles E., A Means of Preventing the Formation of Newton's Rings During Contact Printing of Motion-Picture Film, Mar. pp. 169–171
Ott, Howard F., Dirt-Free Exhaust Hood for Cleaning Film, Oct. pp. 689–690

Page, Charles E., See **Loughlin, Bernard D., et al.**
Palen, Vern W., A Newly Designed Optical Printer, Feb. pp. 98–102
Pike, Frank R., See **Day, John P.**
Ploke, Martin, See **Fischer, Rudolf**
Pores, Edwin B., Television Control Room Human Engineering Problems, Oct. pp. 672–675
Preston, John, See **Olson, Harry F.**

Reese, Warren B., The Xenon-Arc Projection Lamp, June pp. 392–396
Roberts, Howard L., Some Aspects of the Application of Television to the Tracking of Guided Missiles, July pp. 475–477
Roizen, Joseph, Electronic Marking and Control for Rapid Location of Vertical Blanking Area for Editing Video-Tape Recordings, Nov. pp. 732–733
Rosenberger, Harold E., A Look at the Motion-Picture Projector as an Integral Optical-Mechanical System, June pp. 378–384
Ross, Rodger J., Film in Television, June pp. 374–378

Sant, A. J., See **Keene, G. T., et al.**
Schade, Otto H., A Method of Measuring the Optical Sine-Wave Spatial Spectrum of Television Image Display Devices, Sept. pp. 561–566
——, On the Quality of Color-Television Images and Perception of Color Detail, Dec. pp. 801–819
Schendel, A. H., Optical Tracking Instrumentation, Apr. pp. 237–241
Schepler, H. C., Atmospheric Optics, Apr. pp. 225–227
——, Photographic Instrumentation at the Air Proving Ground Center, Apr. pp. 246–248
Schlafly, H. J., Visual Amplification, Mar. pp. 163–164
Schlanger, Ben, New Horizons in Exhibition (Introduction to "Great Britain's National Film Theatre, R. F. Scott), Aug. p. 527
Scott, R. F., Great Britain's National Film Theatre, Aug. pp. 527–530
Scudder, Stanley L., See **Turner, John R., et al.**
Severy, Derwyn M., Photographic Instrumentation for Collision Injury Research, Feb. pp. 69–77
Shelly, Leon, Future Trends in Multi-Voice Films for International Television, Mar. p. 143
Shelton, Charles T., and **Stewart, H. W.**, Pickup Tube Performance With Slow Scanning Rates, July pp. 441–451
Smith, Jack R., See **Dakin, Hollis, et al.**
Stafford, J. W., and **Baumbach, H. L.**, A New Color Timer for Motion-Picture Films, Feb pp. 81–83
Stewart, H. W., See **Shelton, Charles T.**

Templin, E. W., See **Crane, G. R.**
Thompson, Lloyd, Chairman, Progress Committee Report for 1957, May pp. 289–343
——, Errata for May *Journal*, July p. 479
Tinkham, Russell J., Magnetic Recording Media Considerations for Improving Masters and Dubs, Oct. pp. 662–665
Townsley, Malcolm G., International Standardization of Magnetic Sound on Film — A Status Report, Dec. pp. 822–823
Turner, John R., Scudder, Stanley L., and **Deane, Edward H.**, A Machine for Cleaning Motion-Picture Film, July pp. 480–485

Ulffers, Heinz, Xenon High-Pressure Lamps in Motion-Picture Theaters, Abstracted by **Y. G. Hurd**, June pp. 389–392

Vine, B. H., See **Miller, L. D.**
von Behren, Robert A., Magnetic Tape for Video Recording, Nov. pp. 734–737

Wagner, William J., A Method for Controlling the Gray-Scale Equivalent of Colors Used in Live and Filmed Television Scenic and Graphic Art, June pp. 369–373
Wallace, Richard, See **Grunwald, Robert**
Wargo, Lorand, Little, H. M., and **Baumbach, H. L.**, Automatic Printer Light Selector for Bell & Howell Models D and J Printers, Feb. pp. 78–80
Weigel, E. M., See **Fassett, D. W., et al.**
Weiss, Karl, A Method for the Evaluation of the Spectral Characteristics of Color Screens, Sept. p. 605
Weller, William R., See **Delwiche, Donald A., et al.**
——, See **Horowitz, Paul**
Wheeler, Lionel H., A New Additive Color System for Motion-Picture Photography, Nov. pp. 747–749
White, Deane R., International Standardization for Motion Pictures and Films for Television, Dec. pp. 819–821
White, Richard L., and **Lovick, Robert C.**, Glass Filters for Color Printing, Jan. pp. 29–31
Whittaker, J. R., See **Benson, K. B.**

American Standards, Proposals and SMPTE Recommended Practices — 1958 • Volume 67

Number	*Title*	*Issue*	*Page*
PH22.23-1958	8mm Motion-Picture Projection Reels (Revision of Z22.23-1941)	Aug.	537
PH22.28-1958	Focal Lengths and Markings of 35mm Motion-Picture Projection Lenses (Revision of Z22.28-1946)	June	409
PH22.31	Proposed, Motion-Picture Safety Film (Revision of Z22.31-1946)	Feb.	103
PH22.73-1958	Dimensions for 35mm Motion-Picture Film, Perforated 32mm, 2R-2994 (Revision of PH22.73-1951)	June	410
PH22.87-1958	100-Mil Magnetic Coating on 16mm Film, Perforated One Edge (Revision of PH22.87-1953)	June	409
PH22.89-1958	Scene-Change Cueing for Printing 16mm Motion-Picture Film	June	411
PH22.108-1958	Four Magnetic Sound Records on 35mm Film	June	411
PH22.109-1958	Dimensions for 16mm Motion-Picture Film, 1R-2994	Aug.	538
PH22.110-1958	Dimensions for 16mm Motion-Picture Film, 2R-2994	Aug.	539
PH22.111-1958	Picture and Sound Apertures for Continuous Contact Printers for 35mm Release Prints with Photographic Sound Records	June	412
PH22.112-1958	Picture-Sound Separation in 16mm Magnetic Sound Projectors	June	412
PH22.113	Proposed, 16mm Flutter Test Film, Magnetic Type	Feb.	103
PH22.114	Proposed, 16mm Azimuth Test Film, Magnetic Type	Apr.	263
IES-SMPTE Recommended Practice	Proposed, Reporting Photometric Performance of Incandescent Filament Lighting Units Used in Theatre and Television Production	Sept.	606

Index to AMERICAN STANDARDS AND SMPTE RECOMMENDED PRACTICES

JANUARY 1959

For those who would like to keep their standards binder up to date, the Society offers a subscription service. For a fixed yearly fee, those availing themselves of the service will be supplied all American Standards and Recommended Practices which are sponsored by the SMPTE and which are validated during the fee year. Write to the Society for detailed information regarding this service. Individual copies of the following American Standards on Cinematography must be purchased from the American Standards Association, Inc., 70 East 45 Street, New York 17, N. Y.

Subject	*Std. No.*	*Journal*
Apertures, Camera		
8mm	Z22.19–1950*	Apr. 1950
16mm	Z22.7 –1950*	Apr. 1950
35mm (Normal Prints)	PH22.59–1954	Sept. 1954
Apertures, Printer		
16mm Contact (positive from negative)	PH22.48–1956	June 1956
16mm Contact (reversal dupes)	PH22.49–1946 R1955	Apr. 1946
35mm to 16mm (16mm positive prints)	PH22.46–1946 R1953	Feb. 1954
35mm to 16mm (16mm dupe negative)	PH22.47–1946 R1953	Feb. 1954
16mm to 35mm Enlargement Ratio	PH22.92–1953	Jan. 1953
35mm Release Picture-Sound Continuous Contact	PH22.111–1958	June 1958
Apertures, Projector		
8mm	PH22.20–1957	Aug. 1957
16mm	PH22.8 –1957	Aug. 1957
35mm (Normal Prints)	PH22.58–1954	Sept. 1954
35mm (Anamorphic 2.55:1)	PH22.104–1957	Mar. 1957
35mm (Anamorphic 2.35:1)	PH22.106–1957	Dec. 1957
Cores for Raw Stock Film		
16mm	PH22.38–1952	Nov. 1952
35mm	PH22.37–1944* R1953	Sept. 1946
Density Measurements of Film (includes Z38.2.5–1946)*	PH22.27–1947 R1953	Mar. 1948
Edge Numbering, 16mm Film	PH22.83–1952	Nov. 1952
Film Dimensions†		
16mm, 2R-1500 (8 mm)	PH22.17–1954*	May 1954
16mm, 2R-3000	PH22.5 –1953*	Jan. 1954
16mm, 1R-3000	PH22.12–1953*	Jan. 1954
16mm, 1R-2994	PH22.109–1958	Aug. 1958
16mm, 2R-2994	PH22.110–1958	Aug. 1958
32mm, 2R-3000	PH22.71–1957	Mar. 1957
32mm, 4R-3000	PH22.72–1957	Mar. 1957
35mm, Perforated 32mm, 2R-2994	PH22.73–1958	June 1958
35mm, BH-1870	PH22.34–1956	Dec. 1956
35mm, BH-1866	PH22.93–1953*	Jan. 1954
35mm, KS-1870	PH22.36–1954*	May 1954
35mm, DH-1870	PH22.1 –1953*	Jan. 1953
35mm, CS-1870	PH22.102–1956	Dec. 1956
Film Usage, Camera		
8mm	PH22.21–1953	Mar. 1954
16mm, 2R	PH22.9 –1956	June 1956
16mm, 1R	PH22.15–1955	Sept. 1955
35mm	PH22.2 –1954	May 1954
Film Usage, Projector		
8mm	PH22.22–1953	Mar. 1954
16mm, 2R	PH22.10–1956	June 1956
16mm, 1R	PH22.16–1955	Sept. 1955
35mm (Normal Prints)	PH22.3 –1954	May 1954
35mm (Anamorphic)	PH22.103–1957	Mar. 1957
Film Winding		
16mm, 1R	PH22.75–1953	Feb. 1954
Focus Scales, 16mm and 8mm Cameras	PH22.74–1951 R1957	Sept. 1957
Lamps, 16mm and 8mm Projectors		
Base-Up Type	PH22.84–1953*	Jan. 1953
Base-Down Type	PH22.85–1953*	Jan. 1953

* American Standard in process of revision.
R—Reaffirmed.

† Film dimension titles show film width, perforation pitch (without the decimal point) and the perforation shape —BH KS DH CS (Bell & Howell, Kodak Standard, Dubray-Howell, CinemaScope)—or number of rows of perforations (1R, 2R or 4R), depending on which is the significant factor.

Subject	Std. No.	Journal
Lens		
Aperture Calibration	**PH22.90–1953***	Feb. 1954
Focal Lengths, markings, 35mm	**PH22.28–1958**	June 1958
Lens Mounts		
16 & 8mm Cameras	**PH22.76–1951***	June 1951
High-Speed Motion-Picture Cameras (**SMPTE Recommended Practice**)		Aug. 1957
Nomenclature, Film	**Z22.56–1947***	
Reels		
8mm	**PH22.23–1958**	Aug. 1958
16mm	**PH22.11–1953***	Sept. 1953
35mm	**Z22.4 –1941***	Mar. 1941
Reel Spindles, 16mm	**PH22.50–1952**	Dec. 1952
Release Prints, 35mm	**Z22.55–1947***	Mar. 1948
Safety Film	**PH22.31–1958**	Jan. 1959
Screen		
Brightness, 35mm	**PH22.39–1953***	May 1953
16mm	**PH22.100–1955**	Feb. 1956
Sound Transmission	**PH22.82–1951***	Aug. 1951
Sound		
Optical		
16mm	**PH22.41–1957**	Aug. 1957
35mm	**PH22.40–1957***	Nov. 1957
35mm Double Width Push-Pull, Normal	**PH22.69–1948** **R1953**	Nov. 1948
35mm Double Width Push-Pull, Offset	**PH22.70–1948** **R1953**	Nov. 1948
Magnetic		
8mm Stripe	**PH22.88–1956**	June 1956
16mm, 1R		
100 Mil Stripe	**PH22.87–1958**	June 1958
200 Mil Stripe	**PH22.97–1956**	June 1956
Magnetic-Photographic (**SMPTE Recommended Practice**)		May 1955
16mm, 2R		
30 Mil Stripe	**PH22.101–1956**	June 1956
16mm, Picture-Sound Separation	**PH22.112–1958**	June 1958
35mm 200 Mil Track	**PH22.86–1953**	May 1953
35mm Four Records	**PH22.108–1958**	June 1958
Splices		
8mm	**PH22.77–1952**	June 1952
16mm	**PH22.24–1952**	June 1952
Sprockets		
16mm...(**SMPTE Recommended Practice**)*		Feb. 1950
35mm	**PH22.35–1957**	Aug. 1957

Subject	Std. No.	Journal
Television		
Picture Area		
16mm Film	**PH22.96–1954**	Sept. 1954
35mm Film	**PH22.95–1954**	Sept. 1954
16mm Projector, Monochrome Film Chains Full Storage Basis	**PH22.91–1955**	Apr. 1955
Slides and Opaques	**PH22.94–1954**	May 1954
Test Films		
16mm 400-Cycle Signal Level	**PH22.45–1955**	May 1955
3000-Cycle Flutter	**PH22.43–1953**	Nov. 1953
5000-Cycle / 7000-Cycle Sound Focusing	**PH22.42–1955**	May 1955
Buzz-Track	**PH22.57–1955**	May 1955
Multi-Frequency	**PH22.44–1953**	Nov. 1953
Sound Projector	**PH22.79–1950** **R1957**	May 1957
Scanning Beam, Laboratory Type (corrected)	**Z22.80–1950***	Nov. 1952
Scanning Beam, Service Type (corrected)	**Z22.81–1950***	Nov. 1948
Flutter, Magnetic	**PH22.113–1958**	Jan. 1959
35mm 1000-Cycle Balancing	**PH22.67–1948** **R1953**	Nov. 1948
7000-Cycle Sound Focusing	**PH22.61–1949** **R1955**	Jan. 1950
9000-Cycle Sound Focusing	**PH22.62–1948** **R1953**	Nov. 1948
Buzz-Track	**PH22.68–1949** **R1955**	Jan. 1950
Magnetic		
Azimuth Alignment	**PH22.99–1955**	May 1955
Flutter	**PH22.98–1955**	Oct. 1955
Scanning Beam, Laboratory Type	**PH22.66–1948** **R1953**	Nov. 1948
Scanning Beam, Service Type	**PH22.65–1948** **R1953**	Nov. 1948
Theater Test Reel	**PH22.60–1948** **R1953**	Nov. 1948
Test Methods, 16mm Sound Distortion		
Cross Modulation, Variable-Area	**PH22.52–1954**	Oct. 1954
Intermodulation, Variable-Density	**Z22.51–1946***	Jan. 1956
Test Plate		
Resolution Target, 16mm Projector	**PH22.53–1953***	May 1953

* American Standard in process of revision.
R—Reaffirmed.
1R, 2R—Rows of Film Perforations.

JOURNAL OF THE SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

THIS ISSUE IN TWO PARTS

Part I, December 1958 Journal • Part II, Index to Volume 67

CONTENTS—Volume 67 : January—December 1958

Listed on pp. ii-iv are only the papers and major reports from the twelve issues. See the Volume Index for those items which generally appear in the latter part of each issue: Standards, Society announcements (awards, Board meetings, committee reports, conventions, engineering activities news, membership, nominations, section activities), book reviews, current literature, letters to the Editor, education and industry news, new products and obituaries.

SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

55 West 42d St., New York 36

January

Monochrome Television Film Standards . . . . . . K. B. Benson and J. R. Whittaker 1
Laboratory Practices on Films for Television Recommended by Association of Cinema Labs. 6
The Optics of the Lenticular Color-Film Process . . . . Rudolf Kingslake 8
Devices for Making Sensitometric Exposures on Embossed Kinescope Recording Film . . . . Edward M. Crane and C. H. Evans 13
An Instantaneous Electronic Color-Film Analyzer . . Bernard D. Loughlin, Charles E. Page, William F. Bailey, Charles J. Hirsch, Arthur J. Miller and Leonard Giarraputo 17
An Electromechanical Light Valve for Motion-Picture Printers . . . . Frank P. Herrnfeld 27
Glass Filters for Color Printing . . . . Richard L. White and Robert C. Lovick 29
Recording Lip-Synchronized Sound Using a 16mm Magnetic-Optical Sound Projector . . . . Lee T. Askren and Raymond L. Dwyer 32
Ultra-Cold Weather Photography . . . . Richard R. Conger 35

February

Time-Magnification Study of a Rattlesnake Strike . Sam C. Dunton and Henry M. Lester 65
Photographic Instrumentation for Collision Injury Research . . . . . Derwyn M. Severy 69
Automatic Printer Light Selector for Bell & Howell Models D and J Printers . . . . Lorand Wargo, H. M. Little and H. L. Baumbach 78
A New Color Timer for Motion-Picture Films . . . . J. W. Stafford and H. L. Baumbach 81
Use of a Motion-Picture Printer as a Sensitometer . Robert O. Gale and John J. Graham 84
Automatic Announcing Techniques for Television Stations . . . . R. A. Isberg 87
Automatic Cuing of Television Film Projectors . . . . B. F. Melchionni 92
A Studio-Type and a Portable-Type System for Synchronizing ¼-Inch Magnetic Tape With Perforated Motion-Picture Film . . . . Edward P. Kennedy 95
A Newly Designed Optical Printer . . . . Vern W. Palen 98

March

International Television and Bilingual Films: Foreword . . . . Ellis W. D'Arcy, Program Topic Chairman 129
Problems of International Television Broadcasting . . . . T. H. Bridgewater 129
The NARCOM Plan for Transatlantic Television and Other Wideband Telecommunication Services. See Errata, p. 256 of April *Journal* . . . . William S. Halstead 134
Methods of Translating Used in Bilingual Films . . . . Max G. Kosarin 139
A Case History of Bilingual Telecasting in Canada . . . . Jacques Landry 141
Future Trends in Multi-Voice Films for International Television . . . . . . Leon Shelly 143
Averaging Screen-Illumination Readings . . . . Armin J. Hill 144
Beam-Landing Errors and Signal-Output Uniformity of Vidicons . . . . R. G. Neuhauser and L. D. Miller 149
Improved Developmental One-Inch Vidicon for Television Cameras . . . . L. D. Miller and B. H. Vine 154
A Stabilized Monitor for Color Television Picture Quality Control . . . . E. E. Gloystein and N. P. Kellaway 157
Visual Amplification . . . . H. J. Schlafly 163
Survey of Large-Screen Television Projection Equipment . . . . Frank N. Gillette 164
Medium Screen Color Television Projection . . . . S. L. Bendell and W. J. Neely 166
A Means of Preventing the Formation of Newton's Rings During Contact Printing of Motion-Picture Film . . . . Charles E. Osborne 169
A Silver-Recovery Apparatus for Operation at High Current Densities . Nicholas J. Cedrone 172
Cold Mirrors for Projection Heat Control . . . . Balzers Laboratories 175

April

Symposium on Optical Instrumentation for Missile Testing: Foreword . . . . Sidney M. Lipton, Program Topic Chairman 225
Atmospheric Optics . . . . H. C. Schepler 225
Visibility: Detection and Recording of Objects Against a Sky Background . E. P. Martz, Jr. 228
Atmospheric Limitations on Missile Photography . . . . Seibert Q. Duntley 231
Flying Camera Stations . . . . Floyd A. Kinder 234
Optical Tracking Instrumentation . . . . A. H. Schendel 237
A Design and Operational Philosophy for an Ultra-Precision Tracking Mount System for a Missile Test Range . . . . John A. Clemente 242
Photographic Instrumentation at the Air Proving Ground Center . . . . . . H. C. Schepler 246
Automatic-Exposure Control for a High-Resolution Camera . . . . George Economou, Vladimir Luban and Morton Mehr 249

Discussion on Missile Photography . . . . Sidney M. Lipton, Moderator 252
Letter to the Editor: Magnetic/Optical Stereophonic Sound . . . . Steven A. Guy 255
Anamorphic Television Circuit Requirements . . . . Madison Cawein 257
Design and Construction of a Motion-Picture Production Sound Stage . . James A. Larsen 260
Part II—A Directory for Members, pp. 1–80 (includes Officers of the Society, Committees, Financial Report, Constitution and By-Laws, and Awards)

May

Progress Committee Report for 1957. See Errata, p. 479 of July *Journal* . . . . Lloyd Thompson, Chairman 289
Letters to the Editor: Television Receiver Picture-Area Losses. . . . . . Rodney D. Chipp 343

June

A Method for Controlling the Gray-Scale Equivalent of Colors Used in Live and Filmed Television Scenic and Graphic Art . . . . William J. Wagner 369
Film in Television . . . . Rodger J. Ross 374
A Look at the Motion-Picture Projector as an Integral Optical-Mechanical System . . . . Harold E. Rosenberger 378
Film Pulldown Mechanism Based on a Design by Samuel B. Grimson . Frederick T. O'Grady 385
Xenon High-Pressure Lamps in Motion-Picture Theaters. . . . . Heinz Ulffers, Abstracted by Y. G. Hurd 389
The Xenon-Arc Projection Lamp. . . . . Warren B. Reese 392
Automatic Television Film Editing . . . . . . Robert Grunwald and Richard Wallace 397
Some Considerations of Eastman Color Print Film Dye Stability . . . . Paul Horowitz and William R. Weller 401
A Color Timing Method and Calculator for Subtractive Motion-Picture Printers. See Errata, p. 768 of November *Journal* . . . . George T. Keene 404
Convention Plans and Other Prospects. . . . . Barton Kreuzer 413
A Writer-Producer Looks at SMPTE . . . . Charles Brackett 414

July

Military Uses of Television: Foreword . . Max C. Batsel, Program Topic Chairman 441
Pickup Tube Performance With Slow Scanning Rates . . . . Charles T. Shelton and H. W. Stewart 441
New Directions in Aircraft Instrumentation: Foreword . . . . George W. Hoover 452
Development of the Thin Cathode-Ray Tube . . . . William Ross Aiken 452
Development and Applications of Transparent Cathode-Ray Screens . . Charles Feldman 455
Television for Parade Control and Field Exercises. . . . . Hollis Dakin, Frederick L. Martin, Paul A. J. Bue and Jack R. Smith 461
Technical and Production Problems in Military Television Recordings . . . Norman Gray 463
Army Television Research and Development . . William A. Huber and Richard B. Le Vino 465
Television for Use Under Rugged Environmental Conditions . . . J. P. Day and F. R. Pike 470
Television Viewing of Rocket Engine Tests . . . . Jay P. Mitchell 473
Some Aspects of the Application of Television to the Tracking of Guided Missiles . . . . Howard L. Roberts 475
Airborne Closed-Loop Television System . . . . Arthur F. Flacco 477
A Machine for Cleaning Motion-Picture Film . . . . John R. Turner, Stanley L. Scudder, and Edward H. Deane 480
Siemens Dual-Strip 16/16 Projector with Synchronous Motor (Abstract). Heinz Kronenberger 486
Letter to the Editor: 16mm Professional Film — A Proposal . . . . . . R. Rees Lumley 487

August

Causes and Prevention of Static Markings on Motion-Picture Film . . . . . . W. I. Kisner 513
Photographic Duplication of Variable-Area Sound Recordings . . . . J. F. Finkle 518
Joseph T. Tykociner: Pioneer in Sound Recording . . . . John B. McCullough 520
Technical Notes and Reminiscences on the Presentation of Tykociner's Sound Picture Contributions . . . . Joseph E. Aiken 521
An Analytical Evaluation of the Lenticular-Plate Cinemicrograph and the Image-Dissection Process . . . . Charles M. Huggins 523
New Horizons in Exhibition (Introduction to following paper) . . . . Ben Schlanger 527
Great Britain's National Film Theatre . . . . R. F. Scott 527
Design Improvements in High-Wattage Tungsten Filament Lamps for Motion-Picture and Television Studios . . . . Leroy G. Leighton and Alfred Makulec 530
35mm Camera Lenses . . . . Gordon Henry Cook 534

September

A Method of Measuring the Optical Sine-Wave Spatial Spectrum of Television Image Display Devices . . . . . Otto H. Schade 561
Color Exposure for High-Speed Photography of Some Self-Luminous Events . . K. H. Lohse 567
Practical Film Cleaning for Safety and Effectiveness. See Errata, p. 768 of November *Journal* . . . . . D. W. Fassett, F. J. Kolb, Jr., and E. M. Weigel 572
Prolonging the Life of Motion-Picture Release Prints . . . . . Eric C. Johnson 590
A New Series of Lenses for Vidicon-Type Cameras . . . . . John D. Hayes 593
Vidicon Camera Lenses . . . . . Gordon Henry Cook 596
Zoom Lenses for Closed-Circuit Television . . . . . Frank G. Back 598
A Direct-Drive Automatic Iris Control . . . . . Mervin W. LaRue, Jr., John P. Bagby, Stephen F. Bushman, Stanley R. Freeland and David M. MacMillin 600
A Method for the Evaluation of the Spectral Characteristics of Color Screens . Karl Weiss 605
Recommended Practice for Reporting Photometric Performance of Incandescent Filament Lighting Units Used in Theatre and Television Production . . . . . Prepared by the Joint I.E.S.—S.M.P.T.E. Committee on Equipment Performance Ratings 606

October

High-Fidelity Video Recording Using Ultrasonic Light Modulation. See Addendum, p. 746 of November *Journal* . . . . . Leo Levi 657
Magnetic Recording Media Considerations for Improving Masters and Dubs . R. J. Tinkham 662
A Versatile Photographic Recording System for Studio Use . G. A. Brookes and H. A. Manley 666
Television Control Room Human Engineering Problems . . . . . Edwin B. Pores 672
Motion-Picture Laboratory Projection Facilities for Servicing TV Film Programs . . . . . Don V. Kloepfel 676
Printing Motion-Picture Films Immersed in a Liquid—Part III: Evaluation of Liquids . . . . . Donald A. Delwiche, James D. Clifford and William R. Weller 678
A Powered Film-Cleaning Drum . . . . . Harry Brueggemann 686
Dirt-Free Exhaust Hood for Cleaning Film . . . . . Howard F. Ott 689
16mm Super Anscochrome Films . . . . . John L. Forrest 691
Improvements in the Blown Arc for Projection . . Russell J. Ayling and Arthur J. Hatch 693

November

Signal Translation Through the Ampex Videotape Recorder . . . . Charles E. Anderson 721
The Video Processing Amplifier in the Ampex Videotape Recorder . . . . . Ray M. Dolby 726
Factors Affecting the Splicing of Video Tape . . . . . Kurt R. Machein 730
Electronic Marking and Control for Rapid Location of Vertical Blanking Area for Editing Video-Tape Recordings . . . . . Joseph Roizen 732
Magnetic Tape for Video Recording . . . . . Robert A. von Behren 734
Discussion on Video-Tape Recording — Washington, D.C. Convention, 1957 737
Interchangeability of Videotape Recorders . . . . . Charles P. Ginsburg 739
Discussion of Video-Tape Recorder Operations — Los Angeles Convention, 1958 743
Improved Television Viewfinder for Motion-Picture Production . . . . . Karl Freund 745
A New Additive Color System for Motion-Picture Photography . . . . Lionel H. Wheeler 747
The Electrostatic Uniangular Microphone . . . . . Harry F. Olson and John Preston 750
A Portable Sprocket-Type Magnetic Tape or Film Recording System . . . . . G. R. Crane and E. W. Templin 754
A Film-Processing Machine of Flexible Characteristics . . . . I. A. Moon and F. A. Everest 758
A Color Timing Calculating Machine . . . . . G. T. Keene, A. J. Sant and J. D. Clifford 763
Subtractive Color Printer With Geneva Scene-Change Mechanism . . . Harry Brueggemann 769
An Annotated List of Articles Pertaining to the History of Motion Pictures — 1950–1956 (Including Some Historical References on Television) . . . . . Mildred B. Krainock 771

December

On the Quality of Color-Television Images and Perception of Color Detail . . . . . Otto H. Schade, Sr. 801
International Standardization for Motion Pictures and Films for Television. Deane R. White 819
International Standardization of Magnetic Sound on Film — A Status Report . . . . . Malcolm G. Townsley 822
SMPTE Contributions to Standardization in the U.S. . . . . . Frederick J. Kolb, Jr. 824
Recollections and Predictions . . . . . Barton Kreuzer 826
Education—A New Era Begins . . . . . Maurice B. Mitchell 827
The Adventure of Technicolor . . . . . Herbert T. Kalmus 829

Indexes 851

Contents — pages 831 - 850

News Columns

85th Convention—Miami. 831
84th Convention—Detroit 831
Society Awards 836
Honorary Member: Dr. Herbert T. Kalmus . . 836
Fellows. 838
Journal Award: George Lewin 838
Herbert T. Kalmus Gold Medal: Merle L. Dundon. 844
David Sarnoff Gold Medal: Albert Rose . . . 844
Samuel L. Warner Memorial Award: George Lewin 846
Education, Industry News. 847
Employment Service. 848

Advertisers

Bell & Howell Co. 835
Berndt-Bach, Inc.. 843
Birns & Sawyer Cine Equipment Co. 838
Camera Equipment Co. 841
Camera Mart, Inc. 834
Classified. 849
Du Pont 847
Filmline Corp. 849
Gotham Audio Sales Co. Inc.. 840
Kling Photo Corp. 850
Magnasync Mfg. Co., Ltd. 845
Motion Picture Laboratories, Inc. 848
Movielab Color Corp.. 839
Peerless Film Processing Corp. 842
Professional Services 846
Rank Precision Industries Ltd. 844
S.O.S. Cinema Supply Corp. 849
Taylor, Taylor & Hobson Ltd.. 837
Unicorn Engineering Co.. 833
Westrex Corp. 836

Meeting Calendar

American Association for the Advancement of Science, Annual Meeting, Dec. 26–31, Sheraton-Park Hotel, Washington, D. C.

IRE, AIEE, EIA, American Society for Quality Control, National Symposium on Reliability and Quality Control, Jan. 12–14, 1959, Bellevue-Stratford Hotel, Philadelphia.

Institute of the Aeronautical Sciences, Annual Meeting, Jan. 26–29, 1959, Astor Hotel, New York.

Society of Plastics Engineers, Annual Meeting, Jan. 27–30, 1959, Commodore Hotel, New York.

American Physical Society, Annual Meeting, Jan. 28–31, 1959, New Yorker Hotel, New York.

Inter-Society Color Council, 28th Annual Meeting, Apr. 1, 1959, Statler-Hilton Hotel, New York.

85th Semiannual Convention of the SMPTE including International Equipment Exhibit, May 4–8, 1959, Fountainebleau, Miami Beach.

86th Semiannual Convention of the SMPTE including Equipment Exhibit, Oct. 5–9, Statler, New York.

87th Semiannual Convention of the SMPTE, May 1–7, 1960, Ambassador Hotel, Los Angeles.

88th Semiannual Convention of the SMPTE, Fall, 1960, Shoreham Hotel, Washington, D. C.

89th Semiannual Convention of the SMPTE, Spring, 1961, Royal York, Toronto.

90th Semiannual Convention of the SMPTE, Oct. 15–20, 1961, Statler, New York.

Journals Available/Wanted

These notices are published as a service to expedite disposal and acquisition of out-of-print Journals. Please write direct to the persons and addresses listed.

Available

Issues beginning in 1953 available on a nominal basis. Write: Mitchell M. Badler, 1711 Davidson Ave., Bronx 53, N. Y.

Complete set of Transactions, except Nos. 6 and 9, and all Journals published to date, including indexes. All in good condition. Price $500. W. W. Hennessy, RFD #2, Pound Ridge, N. Y.

Complete set of Journals from May 1937 to June 1954, including special volumes and membership directories, excellent condition; also Mar., May 1934 and July 1935 issues. Write: Harry R. Lubcke, 2443 Creston Way, Hollywood 28, Calif. HO 9-3266.

Jan.-Dec. 1950; Jan., Feb., Apr.-Dec. 1951; Jan.–Mar. 1952. Also available are vols. 6 and 7 of The Television Society (British) covering the period Jan. 1950 through Sept. 1955. Write: Andrew N. McClellan, 65 Hillside Drive, Toronto 6, Ont., Canada.

Dec. 1946, Feb.–Dec. 1947, 1948–1955 complete. All copies in perfect condition; for sale as entire lot only. Write: Joseph W. MacDonald, 2414 Sullivant Ave., Columbus 4, Ohio.

Jan. 1947 to Dec. 1957 complete and in perfect condition. For sale only as a set. Write: Charles J. Marshall, 2816 Royalston Ave., Kettering 19, Ohio.

Complete set of Journals Jan. 1949 to Dec. 1958. Perfect condition. What offers? Write: J. G. Jackson, 210 Kingsway South, Port Alberni, B.C., Canada.

All Journals June 1940 to Oct. 1958, except Aug. 1943, Jan., May, Nov. 1946, Dec. 1953. Write: David Waddell, 95 North St., Stoneham 80, Mass.

Feb. 1937; May–Dec. 1938; 1939–1943 complete; 1944 complete except for May; 1945 complete except for Jan.; 1946 complete; 1947 complete except for Apr., May, June; 1948 complete except for June; 1949–1950 complete; Jan., Feb., Mar. 1951; 1952 complete; Feb., Mar. 1953. Also Edison Home Kinetoscope in operating condition, with 4 reels of original film and 2 glass slides. Bill Straley, 123 Arroya Vista Dr., San Antonio 1, Texas.

Wanted

Jan. 1938. E. Raymond Arn, Film Associates, Inc., 4600 S. Dixie Ave., Dayton 9, Ohio.

High-Speed Photography, Vols. 2 & 3. Morton Sultanoff, Terminal Ballistics Laboratory, Aberdeen Proving Ground, Md.

High-Speed Photography, Vols. 1, 2 & 3. John H. Waddell, Fairchild Camera & Instrument Co., 5 Aerial Way, Syosset, N. Y.

Jan. 1938, Jan. 1949. Dept of Cinema, Univ. of Southern Calif., University Park, Los Angeles 7. Att: Herbert E. Farmer.

Transactions No. 1, 1916 ($5 offered); No. 6, 1918 ($10 offered); No. 7, 1918 ($10 offered). James G. Barrick, 1278 West 103 St., N.W., Cleveland 2, Ohio.

sustaining members

of the Society of Motion Picture and Television Engineers

Acme Film Laboratories, Inc.
Alexander Film Co.
Altec Service Company
  Altec Lansing Corporation
Ampex Corporation
Animation Equipment Corp.
Ansco
C. S. Ashcraft Mfg. Co.
The Association of Cinema Laboratories, Inc.
Atlas Film Corporation
Audio Productions, Inc.
The Ballantyne Company
Bausch & Lomb Optical Co.
Bell & Howell Company
Berndt-Bach, Inc.
Burnett-Timken Research Laboratory
Byron, Inc.
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  CBS Television Network; CBS Television Stations; CBS News; CBS Film Sales; Terrytoons
The Calvin Company
Capital Film Laboratories, Inc.
Oscar F. Carlson Company
Century Lighting, Inc.
Century Projector Corporation
Cineffects, Inc.
Cinema-Tirage L. Maurice
Geo. W. Colburn Laboratory ,Inc.
Color Reproduction Company
Color Service Company, Inc.
Comprehensive Service Corporation
Consolidated Film Industries
The Daven Company
Andre Debrie Mfg. Corp.
DeFrenes Company
DeLuxe Laboratories, Inc.
Desilu Productions, Inc.
Dominion Sound Equipments Limited
Du Art Film Laboratories, Inc.
E. I. du Pont de Nemours & Co., Inc.
Dynamic Films, Inc.
Eastern Effects, Inc.
Eastman Kodak Company
Electronic Systems, Inc.
Elgeet Optical Company, Inc.
Max Factor & Co.
Filmline Corporation
Fordel Films, Inc.
General Electric Company
General Film Laboratories Corporation
General Precision Laboratory Incorporated
W. J. German, Inc.
Guffanti Film Laboratories, Inc.
The Harwald Co., Inc.
Frank Herrnfeld Engineering Corp.
Hollywood Film Company
Hollywood Film Enterprises Laboratory
Houston Fearless Company
Hunt's Theatres
JM Developments, Inc.
The Jam Handy Organization, Inc.
Jamieson Film Co.
The Kalart Company, Inc.
  Victor Animatograph Corporation
Kling Photo Corp. (ARRI Div.)
Kollmorgen Optical Corporation
Lorraine Orlux Carbons
J. A. Maurer, Inc.
  Precision Film Laboratories, Inc.
Mecca Film Laboratories, Inc.
Mitchell Camera Corporation
Mole-Richardson Co.
Motiograph, Inc.
Motion Picture Association of America, Inc.
  Allied Artists Products, Inc.
  Columbia Pictures Corporation
  Loew's Inc.
  Paramount Pictures Corporation
  RKO Radio Pictures, Inc.
  Twentieth Century-Fox Film Corp.
  United Artists Corporation
  Universal Pictures Company, Inc.
  Warner Bros. Pictures, Inc.
Motion Picture Printing Equipment Co.
Movielab Film Laboratories, Inc.
Moviola Manufacturing Co.
National Carbon Company, A Division of Union Carbide and Carbon Corporation
National Screen Service Corporation
National Theatre Amusement Co.
National Theatre Supply Company
Neighborhood Theatre, Inc.
Northwest Sound Service, Inc.
Panavision Incorporated
Pathé Laboratories, Inc.
Prestoseal Mfg. Corp.
Producers Service Co.
Radiant Manufacturing Corporation
Radio Corporation of America
Rank Precision Industries Ltd.
Reid H. Ray Film Industries, Inc.
Reeves Sound Studios, Inc.
Charles Ross, Inc.
S.O.S. Cinema Supply Corp.
Shelly Films Limited (Canada)
Southwest Film Laboratory, Inc.
The Strong Electric Company
Technicolor Corporation
Titra Film Laboratories, Inc.
Trans-Canada Films Ltd.
Tri Art Color Corporation
Van Praag Productions
Alexander F. Victor Enterprises, Inc.
Westinghouse Electric Corporation
Westrex Corporation
Wilding Picture Productions, Inc.
Wollensak Optical Company